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ABSTRACT

A planning study for graduate study in the mathematical sciences in Ontario undertaken in 1976-77 resulted in some general and specific observations about the Ontario universities. In general, graduate work in the mathematical sciences is of good quality, and most fields of mathematics are completely covered in one or another university; some fields are indentified for further development. Enrollment projections are considered to be in balance with the number of graduates and job opportunities, although enrollment-to-graduation ratios are low for doctoral students. It is recommended that the universities carefully watch enrollment/graduation data and the employment market for changes. It is also felt that part-time study be made available at the master's level when feasible. Specific recommendations are made for the individual universities' program development efforts. (MSE)

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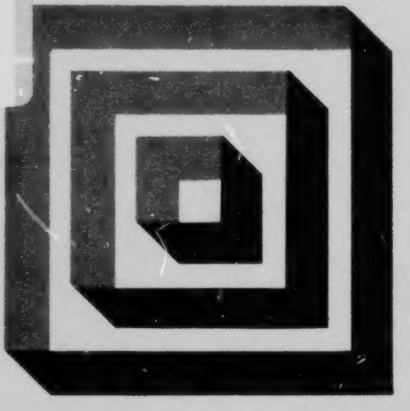
Perspectives and Plans for Graduate Studies



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Advisory Committee on Academic Planning

Ontario Council on Graduate Studies

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PERSPECTIVES AND PLANS FOR GRADUATE STUDIES

19. MATHEMATICAL SCIENCES 1975

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FOREWORD

The Advisory Committee on Academic Planning (ACAP), as presently constituted, was established by the Ontario Council on Graduate Studies at the request of the Council of Ontario Universities in January, 1971. The Advisory Committee's terms of reference were directed broadly toward the effective planning and rationalization of long-term graduate development in Ontario's universities both at the level of individual disciplines and at a more general level. The Advisory Committee's activities are based on the premise that graduate work is the one area of university activity in which specialization among universities, cooperative arrangements and comprehensive planning are most necessary.

In March, 1971, concern over the rising costs for support of graduate work prompted the Ontario government to institute a general embargo on funding for any new graduate programme, that is, one which had no students enrolled on May 1, 1971. This embargo was subsequently modified to include only those disciplines in which over-expansion was felt to be potentially most serious. ACAP was to begin immediately planning studies in those disciplines which remained embargoed.

The disciplinary planning process begins with the formation of a discipline group composed of one representative from each university with an interest in graduate work in the planning area. The discipline group assists in defining the precise academic boundaries of each study, scrutinizes the data collection forms, prepares a list of potential consultants, maintains contact with the consultants during the study, and prepares a commentary on the consultants' report.

The final decision on consultants for the planning study is made by ACAP. The consultants are requested to make recommendations on programmes to be offered in Ontario, desirable and/or likely enrolments, the division of responsibility for programmes among universities, and the desirable extent of collaboration with related disciplines.

While the consultants' report is the single largest element in the final report on the planning study, ACAP considers the statement of each university's forward plans to be most significant. These forward plans are usually outlined prior to the planning study, and are used as a basis for comments from the universities concerned on the consultants' report.

On receipt of the consultants' report, and comments on it from the discipline group and the universities, ACAP begins work on its own recommendations for submission directly to the Council of Ontario Universities. COU considers the input from all sources, and prepares the position of the Ontario university community.

Council of Ontario Universities
Conseil des Universités de l'Ontario

Report and Recommendations concerning graduate studies in Mathematical Sciences

On the instructions of the Council of Ontario Universities, the Advisory Committee on Academic Planning has conducted a planning assessment for the mathematical sciences. The resultant report from ACAP is attached together with the consultants' report and the comments on it by the discipline group and the individual universities. Comments on the ACAP report by the Ontario Council on Graduate Studies, the discipline group, Queen's University, the University of Toronto, and the University of Windsor are also published and follow the ACAP report. The procedure and techniques used for the assessment are described in the ACAP report and are not repeated here. It is important for the reader to read the ACAP report, the comments on it and its attachments in order to understand the recommendations in this report from COU.

The ACAP report and supporting documentation were distributed to COU, OCGS, the Council of Deans of Arts and Science and the discipline group on November 19, 1976. The universities, OCGS, CDAS and the discipline group were asked to submit to COU by December 23, 1976, any comments they wished to make on the ACAP report. COU discussed the report and the comments received at its meeting on January 28, 1977. Following the discussion at that meeting, this Report and Recommendations was prepared and approved by the Council on March 11, 1977. The document is addressed to the Ontario Council on University Affairs and the universities of Ontario.

The following principles have been adopted and will apply to this and all other COU Reports arising out of assessments. It is noted, however, that in view of the recent change in the funding mechanism for graduate studies, the "currently embargoed programmes" referred to in principle, should, for the purposes of this Report, be interpreted to mean programmes in mathematical sciences dealt with in this planning assessment.

1. Discipline assessments by ACAP should form the basis for planning by the universities of their development of graduate studies, particularly PhD programmes. On the basis of these assessments, COU should make its own recommendations on currently embargoed programmes. Each university must retain the freedom and responsibility to plan and implement its own academic development. However, the universities in embarking on a cooperative planning process have signalled their intentions of cooperating with the COU recommendations.

2. Universities generally plan their emphases in graduate study on the bases of related departments, not of single departments. Initially the sequential nature of the discipline planning assessments made this difficult. However, by the summer of 1974, assessments of most of the social sciences, all of the physical sciences, engineering doctoral work, and a number of professional areas were completed. On the information and recommendations available, each university should be able to make decisions concerning its support of graduate programmes in these areas. Amendments to university responses to the individual discipline

planning assessments may then be made in the wider context of a group of related disciplines and amendments to COU's original Reports on an individual discipline may be required.

3. The first concern in planning is to review the quality of graduate opportunities and of students in Ontario universities and to make judgments about how to proceed or not proceed based on quality considerations. The procedures have made use of highly qualified independent consultants who have no direct interest in the universities in Ontario. Accordingly, COU feels bound to accept their judgments about quality where they are stated clearly unless unconvinced that their conclusions about quality are consistent with their evidence. COU's recommendations in the case of programmes which are of unsatisfactory or questionable quality will call for discontinuation or the carrying out of an appraisal, if the continuation of the programme is not crucial to the province's offerings. In some cases, however, there may be a particular need for the programme and the appropriate recommendation will be to strengthen it, with an appraisal following that action. It is also possible that if there were found to be too large a number of broadly based programmes there could be a recommendation to discontinue the weakest; in this case, an appraisal for a more limited programme might be relevant.

4. A second consideration is the scope of opportunities for graduate work in the discipline. Do the Ontario programmes together offer a satisfactory coverage of the main divisions of the disciplines?

5. Numbers of students to be planned for will depend on the likely number of applicants of high quality and in some cases may relate to an estimate of society's needs. Such estimates may be reasonably reliable in some cases and not in others. If the plans of the universities appear to be consistent with the likely number of well qualified applicants and there is either no satisfactory basis for estimating needs or there is no inconsistency between a reasonable estimate of need and the universities' plans, then COU will take note of the facts without making recommendations on the subject of numbers.

   If the numbers being planned for by the universities are grossly out of line with the anticipated total of well qualified students, or a reliable estimate of needs, COU will make appropriate corrective recommendations. Depending on the circumstances, these may call for a change in the total numbers to be planned for and indications of which institutions should increase, decrease, or discontinue. The recommendations in serious cases may need to specify departmental figures for each university for a time. If the numbers being planned for are insufficient, the recommendations may call for expansion, or new programmes, and may have implications for both operating and capital costs.

   Unless there are exceptional circumstances, the recommendations concerning enrolment will not call for a university to refuse admission to any well qualified student who wishes to work in a field in which that university offers a programme and in which it has the capacity to accommodate the student.

6. The quality of graduate programmes is partly dependent on size, and for each programme, depending on how it is designed and its scope, there is a minimum size of enrolment below which quality may suffer. That number cannot be expressed for the discipline as a whole but only for individual programmes depending on their purpose, their resources and their design.

7. Universities will be expected to notify COU if they intend to depart from the COU Report in any way which they believe might have a significant bearing on the provincial plans.

8. Appraisals arising as the result of assessments are to be based on the standards but not necessarily the scope of the acceptable programmes in the province.

General observations concerning mathematical sciences

1. Graduate work in the mathematical sciences in the universities of Ontario is of good quality with at least one Ontario university rated in the top two or three in Canada in many of the fields and each of the four areas of the discipline. The computer science programme at the University of Toronto is exceptional by North American standards.

2. Most fields of the mathematical sciences are reasonably completely covered in one or other of the universities. The consultants did, however, identify certain areas which should be further developed, for example, applied probability.

3. The universities' enrolment projections are considered by the consultants to be generally in balance with the number of graduates and job opportunities. Enrolment in pure mathematics is an exception and the recent trend towards lower enrolment is to be encouraged.

4. Enrolment to graduation ratios for doctoral students give cause for concern; further studies should be undertaken to ascertain the problems and their solutions.

Recommendations

It is recommended that:

1. a) The universities give careful consideration to the comments of the consultants and plan their doctoral admissions to ensure for each of the areas a reasonable balance between the number of graduates and the employment opportunities.

   b) The universities plan for roughly stable full-time enrolments at the master's level but be prepared to adjust their sights in response to any notable change in tne employment market.

   c) The universities examine their enrolment/graduation data to determine the underlying cause for the high ratio of enrolments to graduations and work with the discipline group to establish what action, if any, is needed (see also recommendation 3).

2. Part-time study at the master's level be made available when appropriate and practicable.

3. a) The Mathematical Sciences Discipline Group review the enrolment-employment situation annually and make appropriate recommendations to ACAP to adjust the target objectives if this is warranted.

   b) The discipline group report to ACAP by May 31, 1977, on the seemingly high enrolment/graduation ratios, making specific recommendations if this seems appropriate.

   c) The discipline group, in addition to its normal role, undertake a study of the many recommendations of the consultants in Chapter III that deal with matters of collective concern. The group should report to ACAP before May 31, 1977, on the desirability, feasibility and, where appropriate the implementation of the actions proposed in recommendations 38, 39, 40, 44 and 45 of the consultants' report.

4. The University of Toronto and York University report to ACAP by December 31, 1977, on progress in connection with:

   a) the involvement of York faculty in the supervision of research students at the University of Toronto,

   b) the development of a regular statistical seminar involving the collaboration of both groups, and

   c) the proposed programme in computer science at York, if it is to involve collaboration with the University of Toronto.

5. Carleton University and the University of Ottawa report to ACAP through the Joint Ottawa-Carleton Committee for Graduate Studies by December 31, 1977, on progress towards:

   a) a cooperative programme in the field of information and systems science,

   b) increased collaboration among the statisticians of the two universities, and

   c) the development of a comprehensive joint programme of academic work in computer science for the Ottawa area.

6. Guelph, McMaster and Waterloo universities and the University of Western Ontario discuss the possibility of collaboration in the variety of ways indicated by the consultants and report to ACAP by December 31, 1977.

7. The University of Toronto continue its graduate programmes in all four areas of the mathematical sciences.

8. The University of Waterloo continue its graduate programmes in all four areas of the mathematical sciences.

9. Carleton University

   a) continue its doctoral programmes in pure and applied mathematics and statistics with more precise definition of the fields offered in the applied area, and

   b) implement its interdepartmental programme in information and systems science, after consultation with the University of Ottawa as called for in recommendation 5, and giving full consideration to the consultants' view on the role of statistics and probability in this field.

10. The University of Ottawa

   a) continue its master's programme in pure mathematics, develop and submit for appraisal its proposed MA(T) programme and submit its doctoral programme in pure mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

   b) continue its master's programme in applied mathematics, develop an interdepartmental programme in mathematical economics and submit its doctoral programme in applied mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

   c) submit its interdisciplinary master's programme in general systems and information sciences for appraisal, ceasing to enrol students after December 31, 1977, until a favourable appraisal has been obtained,

   d) submit its master's and doctoral programmes in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained, and

   e) defer further development of its proposed master's programme in computer science pending the results of the discussion called for in recommendation 5.

11. Queen's University continue its doctoral programmes in pure and applied mathematics and statistics and continue to strengthen its master's programme in computer scinece. ACAP endorses the consultants' view that the proposal for a PhD programme in computer science be deferred.

12. McMaster University

   a) continue its graduate programmes in pure mathematics,

   b) complete the reorganization of its graduate work in statistics and submit the revised programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained, and

c) strengthen its faculty with respect to core subjects in computer science and continue its master's programme.

13. The University of Western Ontario

a) continue its master's programme in pure mathematics and submit its doctoral programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

b) continue its graduate programmes in applied mathematics,

c) submit for appraisal its graduate programmes in statistics, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained, and

d) continue its master's programme in computer science but defer implementation of its proposed PhD programme as suggested by the consultants.

14. The University of Windsor

a) continue its master's programme in pure mathematics and submit its doctoral for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

b) continue its graduate programmes in applied mathematics, and

c) strengthen its staff in probability and statistics by the addition of two strong, research-oriented members or submit its doctoral programme in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained.

15. The University of Guelph continue its master's programme in statistics and consider the consultants' comments and suggestions concerning its work in pure and applied mathematics, reporting to ACAP on the results of its deliberations not later than May 31, 1977. If the decision of the university is to retain separate master's programmes in pure and applied mathematics, they should be submitted by September 30, 1977, for review by the Appraisals Committee.

16. Lakehead University

a) continue its master's programme in pure mathematics and applied analysis and consider the consultants' suggestion to submit for appraisal a master's programme in pure mathematics, unrestricted in scope and offering the degree by course work or thesis, and

b) defer until 1979-80 its proposal for a programme in applied computer science in the light of the consultants' comments concerning the need for additional staff and the development of an adequate level of research activity.

17. York University

a) continue its unspecialized master's programme in mathematics,

b) consider the consultants' recommendations concerning part-time studies and/or a specialized MSc programme in applied probability, and

c) give serious attention to the recommendations of the consultants concerning its proposal for a master's programme in computer science.

18. In view of the recent changes in the funding mechanism for graduate studies in the Ontario universities, the Ontario Council on University Affairs take note of the completion of this planning assessment and the COU recommendations which will serve as a basis for university decisions in the field of mathematical sciences.

Notes concerning the recommendations

Re: Recommendation 14

A letter from the University of Windsor on recent action has been published.

February 28, 1977

ADVISORY COMMITTEE ON ACADEMIC PLANNING

ONTARIO COUNCIL ON GRADUATE STUDIES

REPORT TO THE COUNCIL OF ONTARIO UNIVERSITIES
ON
MATHEMATICAL SCIENCES PLANNING ASSESSMENT

October 1976

"The potential usefulness of a mathematical concept or technique in the advance of scientific understanding has very little to do with what one can foresee before the concept or technique has appeared."

"Indeed, who at the time of the writing of Appolonius's book on conic sections in the third century B.C. would have dreamed that almost 2,000 years later, Kepler would have employed his results to describe the motion of the planets?"

F.E. Browder, "Does Pure Mathematics Have a Relation to the Sciences?," *American Scientist*, September-October, 1976.

PROCEDURE

On the advice of the Ontario Council on Graduate Studies, the Council of Ontario Universities, on May 3, 1974, approved ACAP's schedule for planning assessments in 1974-75, which included the conduct of a formal planning assessment of mathematical sciences.

This assessment covers the four areas of mathematical sciences, namely, pure, applied, statistics and computer science. Only the latter area is under embargo but COU agreed that no new graduate programmes would be started in the mathematical sciences until after the planning assessment had been completed (COU meeting April 3, 1975).

The procedure and terms of reference for the assessment, attached as Appendix D, were formally approved by COU on January 10, 1975, following approval by OCGS. The new procedure adopted called for a two-tiered panel of consultants composed of two specialist advisors for each of the four areas and three general consultants, one of whom must be a senior Canadian academic from another discipline.

The Mathematical Sciences Discipline Group was constituted with two members named by each of the eleven interested universities and one observer named by two of the other universities. The membership of the discipline group is given in Appendix E.

The ACAP portfolio for mathematical sciences is held by Professor R. C. Anderson who attends meetings of the discipline group when ACAP representation is necessary.

The group held its first meeting in January, 1975 , to discuss the procedures and consider possible consultants. Ad hoc committees were struck to draw up lists of specialist advisors for each area.

The advisors and consultants finally selected were:

Pure Mathematics - W. A. J. Luxemburg
- N. S. Mendelsohn

Applied Mathematics - I. N. Sneddon
- M. Wyman

Statistics - D. R. Brillinger
- W. H. Kruskal

Computer Science	- J. E. Hopcroft - J. M. Kennedy
Consultants	- G. Birkhoff - D. R. Cox - A. H. Morrish

Professor Morrish served as the senior Canadian academic from another discipline. Brief curricula vitae appear in Appendix G.

The consultants and advisors met for two days in May to discuss the assessment with the executive vice-chairman and with the discipline group. The university visits were begun in May and continued through September. The advisors then wrote area reports on the individual universities. Each report was submitted to the institution concerned for comment. The consultants then prepared their report on the basis of the advisors' reports, the universities' comments and their own observations.

The consultants' report was received by ACAP in April, 1976, and served as the basis for the preparation of this draft ACAP report which was approved at the June meeting. Both reports were distributed to the universities and the discipline group for comment. The final ACAP report was written following receipt of the comments and was sent, together with the various appendices, to OCGS, CDAS and the discipline group for comment and to COU for action.

PLANNING TECHNIQUES

For some years now, the universities of Ontario have been committed to the belief that the quality and effectiveness of graduate study in the province can be ensured only by collective and cooperative action. This implies a mechanism for continuing consultation and agreement so that the plans of each university for each of its disciplines are concerted with those of the other universities. At any given time there will exist a plan for the development of each discipline, with agreed and understood roles for each department; since graduate education is the most advanced formal intellectual activity and is, therefore, undergoing change, it is necessary that such plans be kept under regular review and be subject to ready amendment.

The Council of Ontario Universities has assigned to the Ontario Council on Graduate Studies the task of advising it on the development of such plans and on the steps to be taken to carry them into effect. The standing committee which carries out these tasks for OCGS is the Advisory Committee on Academic Planning. A significant role is also played by the discipline groups, one of which is established for each subject, with one or more representatives from each interested university. Each discipline group has the function of assisting and advising ACAP in connection with its own subject.

The above may give the impression that the planning activity is fragmented on a disciplinary basis. This would, of course, not be acceptable. Since the development of one department in a university should not be considered independently of its contribution to the rest of its university and of the influence of the university as a whole on the department, it is most important that universities as institutions play a central role in the planning process. One of the most effective ways of doing this is by indicating to ACAP, the nature of institutional commitments to a department and institutional aspirations for the department.

The most significant single input to a planning assessment is the set of statements from each university of its plans for its department. When these are subject to collective scrutiny it may be found that their totality constitutes a reasonable plan for the discipline in Ontario, but in any case this set of plans is the first approximation to the provincial plan, which the planning assessment may have to refine if there are duplicated features, lacunae in offerings, too large a total enrolment, or other reasons to recommend altering some of the university plans. The universities are also involved in that the bodies that act on ACAP reports, i.e. both COU and OCGS, are composed of the universities.

The formal documents stating the responsibilities of ACAP and the discipline groups are Appendix F. Briefly summarized, it is ACAP's function to advise on steps to be taken to implement effective provincial planning at the graduate level, to promote the arranging of the graduate programmes of the province in order to enhance and sustain quality and to avoid undesirable duplication, and, when necessary, to carry out formal planning reviews for disciplines. A discipline group has the responsibility of keeping under review the plans for graduate work in the discipline and making regular progress reports to ACAP in connection with graduate work in that subject. To make all this possible, it has been agreed that ACAP may communicate directly with universities and discipline groups, to request necessary information, to discuss reports, to convene meetings, and to make and receive proposals for the future.

The above information has been given in some detail because it constitutes the mechanism currently approved by COU for cooperative graduate work. It is fair to say that in 1971 there was no mutually agreed plan for graduate study in any discipline. Our task is not only to generate the first such plan for each subject but also to ensure that it is kept under continual review.

There are four fundamental components in the plan. The first is analysis of the fields of study, the formats of study which should be available to prospective students in the province. The second is an estimate of overall provincial enrolment at master's and doctoral levels based principally on the likely numbers of highly qualified applicants. In regard to considerations of manpower needs for the province of Ontario, ACAP is conscious of the unreliability of forecasts and, except in special cases, subscribes to the approach proposed in the Macdonald Report (1969):

> The country as a whole and the provinces must be concerned about manpower requirements. This concern can be expressed in the first instance through careful survey and forecastings of manpower needs on a continuing basis. Such forecasts should be given wide circulation. It is reasonable to expect that universities will respond by creating additional opportunities for study in the areas of shortage. In addition, the universities through their counselling services have a duty to advise students about the opportunities in various fields from the standpoint not only of intellectual challenge but also of vocational prospects and social utility. The reaction of prospective students to such forecasts is likely to provide an effective control. We believe the marketplace, if its trends are made explicit, offers an adequate governor to prevent serious surfeit and to encourage movement of students toward fields of opportunity.

The third component of the plan is an indication of the role to be played by each department in terms of the programme it will offer and its academic emphasis. Cooperative arrangements between departments are stressed. The fourth component consists of an examination of the enrolment plans of the universities and consideration as to whether the universities' plans and the predicted enrolment for this discipline are consistent. If not, some appropriate action should be recommended to COU. It will be seen that although there may also be other aspects, these are four necessary components in such a plan.

In the mathematical sciences, an imbalance has appeared between the likely job opportunities as seen by the consultants and the number of doctorates graduating. This problem is discussed in detail in the next section.

One must hasten to add that the future is uncertain and that to forecast intellectual trends, student interests, and employment markets five years hence is to undertake to examine many variables. Of course, this is not a new exercise since all universities have had to make decisions about building, staff hiring, library expansion, equipment investment and so forth and have done so on a basis of similar forecasts. Perhaps sometimes the forecasts have been more intuitive than consciously recognized, but they have certainly been there. All that is new is to make such plans systematically for the province.

It will be realized that, at a minimum, the planning procedures we have indicated require annual reporting of enrolments and annual examination of admission standards. When there are indications from these or other sources that some aspects of the plan for the discipline are not being realized, it will be necessary for ACAP to initiate a review. Such a review would usually not involve outside consultants. Whether the impetus came from a discipline group, a university or ACAP itself comments would be sought from all concerned and the review would culminate in a report to COU recommending an amendment to the plan.

If a university notifies ACAP of its intention to depart from its accepted role (for example to enrol students in a field not included in its understood plan), ACAP will review the situation in the light of any other such notifications it may have received and any other pertinent factors. The extent of any further study would depend on the situation, but if ACAP felt that the university's new plan could be a cause for concern, its first step would be to seek full discussion with the university. Normally there would already have been discussion in the discipline group and between universities and the university would have reached its intention after a careful examination of the general situation of graduate study in the discipline. Thus the ACAP decision would be straightforward and a change in plan would be recommended to COU through OCGS. If, however, ACAP still felt that there was a probability that the university's action might be found, on further study, to be potentially harmful to the system, it would probably next seek comment from other universities concerned and from the discipline group. In any case, ACAP would eventually make some recommendation to COU (through OCGS) concerning the variation.

It is difficult without a concrete case to speculate on likely recommendations, but perhaps two hypothetical situations will illustrate the extremes. If a university indicated that, without any marked change in the academic emphasis of its department, it proposed to arrange to enrol somewhere around 70 graduate students instead of about 50, and if there were no changes at other universities and no potential developments which could be substantially affected, ACAP would presumably simply notify COU of the university's intention and recommend that it be recognized as an alteration in plan for the discipline. At the other extreme if a university proposed to begin a new programme designed to enrol fairly soon some 30 PhD students in a field of the discipline already well covered in other universities, it would clearly be necessary to obtain reaction from the discipline group and from other universities and perhaps even some expert advice, in order for ACAP to generate an advisory position concerning the impact of the proposal on the system and suggestions to the university concerned and to COU. As has been noted, if there had been advance interuniversity discussions and agreement, this would be a positive factor in ACAP's assessment, but there is of course the possibility that the recommendation would call for modification of the university's intention; we take that to be the obvious consequence of system planning. Of course, the university could decide to act in a manner contrary to a COU recommendation, accepting whatever consequences would result; we take that to be the basic right of university autonomy. It is understood that a university will not act in this way without the notification and review described in the preceding paragraph.

GENERAL RECOMMENDATIONS

This section contains recommendations of a general nature applicable to all four areas of the mathematical sciences.

References following a recommendation refer to the consultants' report. It is important to note that the ACAP report should be read in conjunction with the consultants' report which provides background for the recommendations made here. Also, following the custom used for other disciplines, ACAP recommendations are prefixed with the symbol 'C' to avoid confusion with the numbering in the COU report.

Mathematics is a central discipline which has long been essential to the development of high quality graduate programmes in the physical sciences and has become increasingly important to graduate studies in the social and life sciences as well. For such disciplines, graduate study at the master's level is, by general agreement, a matter of institutional planning. Master's programmes are offered at eleven of the fifteen provincial universities, but involvement of the remaining four, either through cooperative ventures with other universities or on their own, might be anticipated at some time in the future.

Quality and Scope

The consultants have many encouraging things to say about mathematics in the universities of Ontario. They note that the activity in mathematical sciences in the province is superior in terms of breadth and quality to that in any other province in Canada. They go on to state "that in many of the fields and each of the areas at least one Ontario university is to be rated in the top two or three in Canada." Although the level of mathematical research in any Ontario university does not rank in the same class as that in the small number of best centres in the world, computer science at the University of Toronto is exceptional and rates in the first half-dozen offerings in North America. Also, the report notes "the presence of a number of individuals with international reputations, some of whom are among the world leaders in at least some special field."

ACAP is pleased to record the favourable opinion of the consultants on the quality of graduate studies and research in mathematics in Ontario and encourages the universities to pursue the goal of continued improvement. Toronto and Waterloo particularly, are urged to consider the comments and recommendations of the consultants concerning their potentials as major centres for graduate studies and research in mathematics. It is noted that, although most of the fields of mathematics are said to be reasonably completely covered in one or other of the universities, there are some fields in which further development should be encouraged (see pages A-13 and A-79).

TABLE I

MATHEMATICAL SCIENCES IN ONTARIO

DOCTORAL ENROLMENTS AND DEGREES GRANTED

	Pure		Applied		Statistics		Computer Sc.	
	FT	PT	FT	PT	FT	PT	FT	PT
1970-71								
Enrolment	144	21	64	10	42	8	68	6
Degrees Granted	25	4	11	1	6	4	-	4
1971-72								
Enrolment	140	22	61	11	38	7	75	10
Degrees Granted	21	9	13	4	7	2	4	4
1972-73								
Enrolment	142	20	44	12	38	10	73	16
Degrees Granted	32	8	14	3	5	1	6	4
1973-74								
Enrolment	132	15	36	11	32	6	92	15
Degrees Granted	19	7	11	2	6	3	5	9
1974-75								
Enrolment	103	17	32	9	35	19	80	15
Degrees Granted	32		8		8		23	
1975-76								
Enrolment	99	21	36	7	39	17	85	21
Degrees Granted	15		5		8		20	

Includes Carleton, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western and Windsor universities.

SC:ld

June 17, 1976

Also, the enrolment and graduation statistics in Table I clearly indicate that either the times required to obtain degrees are notably longer than recommended by the consultants on pages A-14 and A-15 or there are large numbers of drop-outs in mathematics. Of course the numbers may reflect a combination of both factors but in any event there would appear to be a problem associated with excessive demands on the candidates or inadequate admission standards or poor control of the admissions process. This aspect of doctoral studies should be examined by the discipline group as suggested in recommendation C3.

ACAP supports the views expressed by the consultants on pages A-19 and A-74 concerning the relationship between the quality of graduate study in mathematics and programme size. In summary it is noted "that most research students should work in centres where there are an appreciable number, five or more research students in their area, but that other departments with the facilities to provide programmes of the necessary quality should not be barred from doing so" and that "it is not economically viable to mount a thorough programme of course work within an area without a good number of students." This important facet of graduate study in mathematics is mentioned on page A-19 and discussed fully on pages A-74 and A-75 (see also recommendation C3 below).

Employment Opportunities and Enrolments

Following a detailed consideration of employment opportunities, beginning on page A-19 of their report, the consultants conclude that:

> a production rate of 50 PhDs per year for Ontario would lead to unemployment problems: a figure of 40 PhDs per year would be more realistic for 1975-80 (page A-23),

and

> no limitations should be placed on the number of master's candidates other than the supply and interest of suitably qualified students (age A-25).

ACAP accepts and supports these conclusions for the areas of pure mathematics, applied mathematics and statistics and the suggestion that for these three areas the 30 PhD graduates per year should be roughly equally divided among the three areas. ACAP recognizes that the job opportunities in computer science justify a somewhat higher output and proposes that the situation be reviewed regularly by the discipline group. The universities are asked to reexamine their admission plans in the light of the situation revealed by the consultants.

In applied mathematics and statistics, the suggested numbers are reasonably compatible with recent enrolment and graduation figures but it is noted that recent enrolments are smaller than the sum of the individual university enrolment projections for the next five years. In the case of pure mathematics, a similar comparison shows quite significant discrepancies but it is noted that the more recent enrolment figures do show a trend towards a better balance. The field of computer science is sufficiently new and its applicability of such potential breadth that ACAP hesitates to support any major cut-back in the present level of activity in this area. At the same time, the universities concerned are advised to monitor the employment situation very closely and to modify their plans for development in this field in an appropriate way.

It is also suggested that the proposed target numbers might be adjusted slightly upward on the basis of foreign students supported by CIDA or other similar agencies and committed to return to their homes on graduation. Another factor affecting target numbers would be the extent to which a change in the emphasis of the programmes might improve the possibilities for non-academic employment. ACAP supports the consultants when they urge on page A-29 "that the emphasis of graduate instruction and reasearch be on increasing quality and relevance; the quantity should remain constant or be allowed to decrease."

Recommendation C1

> It is recommended that the universities give careful consideration to the comments of the consultants and plan their doctoral admissions to ensure for each of the areas a reasonable balance between the number of graduates and the employment opportunities.
>
> It is also recommended that the universities plan for roughly stable full-time enrolments at the master's level but be prepared to adjust their sights in response to any notable change in the employment market.
>
> It is strongly recommended that the universities examine their enrolment/graduation data to determine the underlying cause for the high ratio of enrolments to graduations and work with the discipline group to establish what action, if any, is needed (see also recommendation C3, page 11).

Part-time Study

The consultants indicate on pages A-76 and A-77, their general support for part-time study at the master's level noting, in particular, the desirability of this approach in the larger population centres and for teachers and others whose work has a substantial connection with mathematics. Statistics and computer science are seen as particularly appropriate for part-time study.

Recommendation C2

It is recommended that part-time study at the master's level be made available when appropriate and practicable.

Cooperation and the Role of the Discipline Group

After comparing the relatively independent universities of Ontario with some of the more centralized state systems in the United States, the consultants comment on page A-27 that "In the present climate, it seems that cooperation between universities in Ontario must be fostered."

ACAP notes that the many comments, suggestions and recommendations scattered throughout the consultants' report concerning the need for cooperation involve three different levels of interaction:

i) collaboration of a general nature with respect to such matters as seminars, library acquisitions, mobility of students across the system, etc.,

ii) more formal arrangements involving the participation of staff at one institution as research supervisors or members of graduate student advisory committees at other institutions, and

iii) cooperative or joint programmes involving the direct participation of two or more universities.

The difficulties in the way of rapid evolution of extensive cooperation are significant and as the consultants point out, the implementation of collaborative arrangements is more likely to be effective through mutual agreement than by imposition. They suggest a number of matters that could usefully be undertaken by an interuniversity committee, possibly the discipline group.

Recommendation C3

It is recommended that the Mathematical Sciences Discipline Group review the enrolment-employment situation annually and make appropriate recommendations to ACAP to adjust the target objectives if this is warranted.

It is also recommended that the discipline group report to ACAP by May 31, 1977, on the seemingly high enrolment/graduation ratios, making specific recommendations if this seems appropriate.

It is also recommended that the discipline group, in addition to its normal role, undertake a study of the many recommendations of the consultants in Chapter III that deal with matters of collective concern. The group should report to ACAP before May 31, 1977, on the desirability, feasibility and, where appropriate the implementation of the actions proposed in recommendations 38, 39, 40, 44 and 45 of the consultants' report.

Although the other recommendations of Chapter III tend to be more institutional in character, ACAP recognizes the merit of some wider discussion of them and anticipates that the group may wish to comment on some of them. In the same vein, attention is also drawn to comments in other parts of the report such as those on the coverage of fields, especially in applied mathematics (recommendation 12, page A-45), on the time required to achieve a degree (pages A-14 and A-15) and on the relationship between graduate study and research (pages A-14 and A-78).

Recommendations proposing specific areas of cooperation between specific institutions will be set out in the next section. In this connection, ACAP is particularly pleased to note the creation of the Joint Ottawa-Carleton Committee for Graduate Studies which should help to promote continued improvement of the graduate offerings in the Ottawa region.

UNIVERSITY RECOMMENDATIONS

This section contains a brief comment on each of the four areas of mathematics followed by several general observations which the universities are asked to bear in mind while considering their individual recommendations. Those portions of the recommendations calling for the cooperation of two or more universities have been extracted and appear at the beginning of the list. The order of presentation used by the consultants is retained, i.e. Toronto, Waterloo, Carleton, Ottawa, Queen's, McMaster, Western, Windsor, Guelph, Lakehead and York. The recommendations have been assembled in a manner to present, for each university, ACAP's advice on all four areas including reference back to the recommendations on cooperation.

It is important to consider ACAP's recommendations in the context of the consultants' report.

Pure Mathematics

The consultants are generally satisfied with the high standards that have been maintained in this area but they do express concern that "the graduate education of a doctoral student should not be narrowly centred around the topic of the dissertation." The mismatch between numbers of graduates and employment opportunities is greatest in this area and ACAP supports the views of the consultants that the universities should reconsider their projected enrolments, that research activity should be less dependent on the existence of graduate students and that graduate students should be advised to follow at least one applied topic to a reasonably advanced level.

Applied Mathematics

The extremely broad coverage and rapidly changing boundaries of applied mathematics make a precise definition of the field difficult. Also, as suggested by the consultants, some kinds of application have a relatively short-span of activity and excitement and "an appreciable proportion of applied mathematics faculty must be prepared to change their main fields of interest, possibly several times. Continuous reappraisal of topics of interest is required." Their concern "that the full implications of a broadening of the role of applied mathematics have yet to be implemented, in Ontario or elsewhere" prompted ACAP to refer their recommendation 12 (page A-45) to the discipline group for consideration.

Statistics

This area divides generally into applied probability and statistics. The consultants note, with some exceptions, a surprising province-wide weakness in the former but offer no general recommendations on the matter. They "believe that the effective demand for statisticians with a graduate qualification will persist and probably increase, provided the statistical training achieves a satisfactory balance between theory and application." ACAP reflects their concern about the range of quality and research activity of the faculty and of the numbers and qualities of the graduate student bodies and emphasizes the need for each university to give very serious consideration to the consultants' comments on organizational problems in this area (page A-53).

Computer Science

It is pointed out that while Toronto and Waterloo offer fairly complete coverage of all areas at both master's and doctoral levels, other programmes in the province are more specialized and tend towards computer applications, systems engineering and hardware. The danger of isolation of computer science from the other mathematical sciences is noted and the need to strengthen the ties between this field and the relevant areas of pure mathematics (especially algebra), applied mathematics, numerical analysis and statistics is emphasized. ACAP reiterates the consultants' recommendation (page A-63) "that attention be concentrated on staying in the forefront of current computing research and development, rather than on growth or on the duplication of existing programmes."

An Important Note

ACAP wishes to emphasize at this point that all of its recommendations proposing continuation or introduction of programmes according to the universities' plans should be interpreted in the light of the very strong reservations expressed by the consultants about enrolment projections and employment opportunities. This will be of particular concern to those in pure mathematics but the discipline group would do well to keep a careful watch on enrolments and projections for all areas.

Cooperation

Recommendations for cooperation are presented first, followed by individual university recommendations. Although no specific recommendation has been included here, ACAP wishes to draw attention to the last section of recommendation 30 in which the consultants call for increased attention (by the computer science group at Toronto) to cooperation with the staff of other Ontario universities.

Recommendation C4

It is recommended that the University of Toronto and York University report to ACAP by December 31, 1977, on progress in connection with:

- i) the involvement of York faculty in the supervision of research students at the University of Toronto (see recommendation 11, page A-42),
- ii) the development of a regular statistical seminar involving the collaboration of both groups (see recommendations 20 and 29, pages A-55 and A-62), and
- iii) the proposed programme in computer science at York, if it is to involve collaboration with the University of Toronto (see recommendations 30 and 37, pages A-64 and A-71).

Recommendation C5

It is recommended that Carleton University and the University of Ottawa report to ACAP through the Joint Ottawa-Carleton Committee for Graduate Studies by December 31, 1977, on progress towards:

- i) a cooperative programme in the field of information and systems science (see recommendations 15 and 16, pages A-47 and A-48),
- ii) increased collaboration among the statisticians of the two universities (see recommendations 22 and 23, pages A-57 and A-58), and
- iii) the development of a comprehensive joint programme of academic work in computer science for the Ottawa area (see recommendations 32 and 33, pages A-66 and A-67).

Recommendation C6

It is recommended that Guelph, McMaster and Waterloo universities and the University of Western Ontario discuss the possibility of collaboration in the variety of ways indicated by the consultants and report to ACAP by December 31, 1977, (see recommendations 21 and 28, pages A-56 and A-61 as well as comments in Chapter III).

University of Toronto

The University of Toronto offers doctoral work in all four areas of the mathematical sciences, its computer science programme being among the best half dozen in North America. The advisors considered the Toronto graduate students in pure mathematics to be the best they met. This is reflected in the consultants' suggestion that Toronto produce half of the suggested total annual number of PhDs in this area. They suggest that a greater degree of interaction between all of the areas of mathematics would be desirable and emphasize in this connection, the need for more adequate housing to bring all of the faculty together. They also suggest an internal review to examine several specific aspects of pure mathematics and its interaction with the other areas. In commenting on the De Lury report on applied statistics, they recommend that the future of applied statistics should be considered in the context of statistics as a whole to achieve a greater merging of theory and application.

ACAP is confident that the university will give due consideration to the general recommendations of the consultants and of the De Lury report.

Recommendation C7

> It is recommended that the University of Toronto continue its graduate programmes in all four areas of the mathematical sciences (see recommendations 2, 13, 20 and 30 of the consultants' report).
> See also recommendation C4, page 15.

University of Waterloo

The University of Waterloo has a Faculty of Mathematics, consisting of five departments including a Department of Combinatorics and Optimization. Doctoral programmes are offered in all four ACAP areas. The consultants note that there are some faculty members who have established international reputations and the combinatorics and optimization component of the staff is one of the strongest of its kind in the world. The computer science programme was judged to be "one of the best dozen or so in North America." In the statistics area, concern was expressed about some weakness in probability which appears to be a province-wide problem. Intrauniversity consulting in statistics should be strengthened as well as interuniversity collaboration with Guelph, McMaster and Western. ACAP recommends that Waterloo take note of the consultants' comments on pages A-47 and A-65 concerning admission standards.

Recommendation C8

> It is recommended that the University of Waterloo continue its graduate programmes in all four areas of the mathematical sciences (see recommendations 3, 14, 21 and 31 of the consultants' report).
> See also recommendation C6, page 15.

Carleton University

Carleton University offers the PhD in all four areas of the mathematical sciences; computer science being offered jointly by the Department of Mathematics and the Department of Systems Engineering. In the area of pure mathematics the consultants were impressed by the steady stream of distinguished visitors at Carleton and by the 'algebra days'. They also found the quality of the doctoral theses to be "high if not outstanding." Work in the applied area centres around information and systems engineering and should be encouraged and strengthened. At the doctoral level, there is a need to define more clearly, the fields offered for dissertation in the programme. Concern was expressed about the unevenness of the faculty in statistics and also about the weak statistical content of the master's programme in information and systems science. Collaboration with the University of Ottawa was reccommended in all areas except pure mathematics but particularly in computer science where it was anticipated that a joint, wide-ranging, high quality programme could be developed.

Recommendation C9

It is recommended that Carleton University:

i) continue its doctoral programmes in pure and applied mathematics and statistics with more precise definition of the fields offered in the applied area,

ii) implement its interdepartmental programme in information and systems science, after consultation with the University of Ottawa as called for in recommendation C5, and giving full consideration to the consultants' view on the role of statistics and probability in this field.

(See recommendations 4, 15, 22 and 32 of the consultants' report.)
See also recommendation C5, page 15.

University of Ottawa

The University of Ottawa offers a PhD in the areas of mathematics but has no graduate programme at present in computer science. Although the master's theses in pure mathematics were judged to be of acceptable quality, the number of doctoral graduates and the quality of those theses examined led the consultants to suggest appraisal. ACAP supports the suggestion that the doctoral programme should be appraised and that the proposed MA(T) programme should be developed. The doctoral programme in applied mathematics has not attracted Canadian students and has produced only two graduates in the last five years. The university's intention to expand the programme into mathematical physics is considered to be ill-advised and the department is urged instead, to develop a graduate programme in mathematical economics, tailored to the needs of the Ottawa area. The statistics group is new and has not yet attracted students into the graduate programmes. ACAP supports the recommendation for appraisal. The existing activity in computer science is handled either in the interdisciplinary programme in general systems and information science or in the electrical engineering programme. ACAP feels that any further development in this area should take the form of a cooperative programme with Carleton rather than the independent development of an Ottawa proposal.

Recommendation C10

It is recommended that the University of Ottawa:

i) continue its master's programme in pure mathematics, develop and submit for appraisal its proposed MA(T) programme and submit its doctoral programme in pure mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
ii) continue its master's programme in applied mathematics, develop an interdepartmental programme in mathematical economics and submit its doctoral programme in applied mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
iii) submit its interdisciplinary master's programme in general systems and information sciences for appraisal, ceasing to enrol students after December 31, 1977, until a favourable appraisal has been obtained,
iv) submit its master's and doctoral programmes in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
v) defer further development of its proposed master's programme in computer science pending the results of the discussion called for in recommendation C5.

(See recommendations 5, 16, 23 and 33 of the consultants' report.)
See also recommendation C5, page 15.

Queen's University

Queen's University offers doctoral studies in the three areas of mathematics and a master's programme in computer science. The consultants commend the quality and breadth of the offerings in pure mathematics as well as the contributions of the visitors and summer programmes to the graduate activity. The interdepartmental programme in control theory is of high quality and provides, along with the work in quantum theory, the major focus in applied mathematics. Broadening into non-academic areas and closer coordination with computer science are indicated. The services and opportunities provided by STATLAB are praised. There are suggestions for increased autonomy for the statistics group and for a reconsideration of the requirements for the PhD in this area. ACAP urges the university to consider the suggestions made in these areas. In noting the uneven quality of master's theses in computer science and a less than impressive research output by the faculty, the consultants recommend postponement of the proposed PhD programme until the MSc programme has been strengthened and additional staff appointments have been made. It is also emphasized that there is really no need for a third PhD programme in the province at this time.

Recommendation C11

> It is recommended that Queen's University continue its doctoral programmes in pure and applied mathematics and statistics and continue to strengthen its master's programme in computer science. ACAP endorses the consultants' view that the proposal for a PhD programme in computer science be deferred (see recommendations 6, 17, 24 and 34 of the consultants' report).

McMaster University

McMaster University offers doctoral studies in pure mathematics including probability theory and master's programmes in statistics and computer science. Although the quality and reputation of the faculty in several fields of pure mathematics were recognized, the quality of both master's and doctoral theses was seen to be acceptable but not outstanding. The desirability of giving attention to some aspects of applied mathematics in the programme was noted. Concern was expressed about the fragmentation of graduate work in statistics and the urgent need to unify graduate teaching and research in this area. The heterogeneity of faculty quality and the narrow scope of the MSc theses in statistics were mentioned although the existence of impressive strength in another department was also noted. ACAP is pleased to note that the university is undertaking a reorganization of its graduate work in statistics and supports the consultants' recommendation for appraisal. Finally, the interdisciplinary MSc programme in computer science appears to be attractive and is supported by related research strength in chemical and electrical engineering, but does not appear to have the desirable strength in theoretical computer science.

Recommendation C12

It is recommended that McMaster University:

i) continue its graduate programmes in pure mathematics,
ii) complete the reorganization of its graduate work in statistics and submit the revised programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

iii) strengthen its faculty with respect to core subjects in computer science and continue its master's programme.

(See recommendations 7, 25 and 35 of the consultants' report.) See also recommendation C6, page 15.

University of Western Ontario

The University of Western Ontario offers the PhD in the three areas of mathematics and a master's degree in computer science. The undergraduate honours programme at Western is of high quality and the students are well prepared for master's work. The consultants expressed some concern over the narrowness of the PhD programme in pure mathematics. The main research strength is in summability theory and there is also some strength in algebra. The consultants feel that the addition of several strong research mathematicians is vital to the maintenance of a strong doctoral programme. They also suggest a closer liaison with the applied mathematicians, several of whom enjoy international reputations. The latter area is well covered at the master's level but the department is unlikely to achieve its full potential until a number of organizational problems involving mathematics, mathematical physics and theoretical physics are resolved. ACAP joins the consultants in hoping that the internal reviews now under way will produce some positive recommendations for applied mathematics at Western. The consultants comment on sources of strength in statistics but also note certain weaknesses in relation to course offerings and theses. ACAP is pleased to learn that the university is proceeding with the unification of the organizational arrangements for statistics and supports the consultants' recommendation for appraisal. The master's programme in computer science has been very successful but the consultants believe that raising admission standards would be more beneficial than increasing enrolment. They also indicate that the overall research record of the department is not strong enough to justify the proposed doctoral programme and suggest that the occasional PhD student might proceed under a cooperative arrangement with Waterloo and Toronto.

Recommendation C13

It is recommended that the University of Western Ontario:

i) continue its master's programme in pure mathematics and submit its doctoral programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
ii) continue its graduate programmes in applied mathematics,
iii) submit for appraisal its graduate programmes in statistics, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
iv) continue its master's programme in computer science but defer implementation of its proposed PhD programme as suggested by the consultants.

(See recommendations 8, 18, 26 and 36 of the consultants' report.)
See also recommendation C6, page 15.

University of Windsor

The University of Windsor offers doctoral studies in the three areas of mathematics but has no graduate work in computer science. The consultants expressed concern about the viability of the PhD programme in pure mathematics. The faculty is young and tenured and a vacancy for a necessary senior mathematician seems unlikely. The enrolment is low; only three doctorates have been graduated since the programme began. Again, doubts were raised as to the number of well qualified Canadian students that will be attracted to the programme. In applied mathematics, doctoral work centres around the mechanics of solids and fluids and applied analysis. There is good cooperation between the mathematicians and the engineering departments. The doctoral theses are of current interest and good quality. The graduate programmes in statistics are of satisfactory quality but the consultants point out the need for at least two strong research-oriented appointments to the faculty. Cooperation between statisticians and other faculty members throughout the university is commended. ACAP wishes to draw to the university's attention the possibilities of cooperation with other universities.

Recommendation C14

It is recommended that the University of Windsor:

i) continue its master's programme in pure mathematics and submit its doctoral programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
ii) continue its graduate programmes in applied mathematics,
iii) strengthen its staff in probability and statistics by the addition of two strong, research-oriented members or submit its doctoral programme in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained.

(See recommendations 9, 19 and 27 of the consultants' report.)

University of Guelph

Guelph offers a master's programme in pure mathematics, applied mathematics and statistics. At present, there are no students in the pure mathematics programme; the applied mathematics programme has enrolled one part-time student. The consultants made no recommendations concerning either of these programmes but suggested that Guelph might offer a single set of courses at the master's level emphasizing statistics. They suggest that the current programme in statistics should be "continued, fostered and better advertised in view of the healthy atmosphere generated by the applied research carried out at the University." The master's theses from this programme are of high quality. The consultants suggest that doctoral students from Waterloo might be encouraged to work with Guelph faculty on agricultural and biological problems. In the computer science area Guelph has withdrawn its plans for a master's programme. Again, it is suggested that Guelph arrange to have its faculty become involved with programmes at other universities.

Recommendation C15

> It is recommended that the University of Guelph continue its master's programme in statistics and consider the consultants' comments and suggestions concerning its work in pure and applied mathematics, reporting to ACAP on the results of its deliberations not later than May 31, 1977. If the decision of the university is to retain separate master's programmes in pure and applied mathematics, they should be submitted by September 30, 1977, for review by the Appraisals Committee (see recommendation 28 and pages A-39, A-50 and A-61 of the consultants' report). See also recommendation C6, page 15.

Lakehead University

Lakehead offers a master's programme in pure mathematics and has a proposal for an interdisciplinary master's programme in applied computer science. The graduate programme in pure mathematics is founded on a firmly established, well balanced undergraduate programme and is actively supported by all faculty members. The theses compare favourably with those produced at the other universities but the consultants note a failure to attract Canadian students. They suggest that the programme be expanded to include all fields of pure mathematics. No recommendation was made about the computer science proposal as it is only at a preliminary stage. However, the university was advised to consider the need to attract sufficient Canadian students and to allow the faculty enough time to become active in research before implementing the programme.

ACAP does not accept the university's comment "We believe that, while the ACAP advisers were careful to restrict their comment to the area of pure mathematics, we are justified in reading into these comments approval of our entire program, and plan to proceed on this basis." Apart from the field of applied analysis, the areas of applied mathematics and statistics do not show adequate staffing to mount an unrestricted programme.

Recommendation C16

It is recommended that Lakehead University:

i) continue its master's programme in pure mathematics and applied analysis and consider the consultants' suggestion to submit for appraisal a master's programme in pure mathematics, unrestricted in scope and offering the degree by course work or thesis,

ii) defer until 1979-80 its proposal for a programme in applied computer science in the light of the consultants' comments concerning the need for additional staff and the development of an adequate level of research activity.

(See recommendation 10 and page A-70 of the consultants' report.)

York University

York University offers an unspecialized MA in mathematics and plans to develop a master's programme in computer science. Special strength exists in combinatorial group theory (best in the province), classical analysis and probability, but there is weakness in other areas, particularly in statistics. Faculty resources are not used to the best advantage and the existing programme suffers from small enrolments. ACAP is convinced that cooperation with other nearby institutions, notably Toronto, is essential if the full potential of York's faculty is to be realized without major additions to the staff. Perhaps members could serve as thesis advisors to doctoral students at Toronto and Waterloo. It is noted particularly, that the strength in statistics at Toronto and York are complementary and cooperation in this area would be beneficial to both programmes. The consultants suggest that York should develop its work in probability for part-time studies and should consider a specialized MSc in applied probability. If the proposal for a programme in computer science is developed, two new appointments should be made and the details of cooperative arrangements with other universities should be spelled out.

Recommendation C17

It is recommended that York University:

i) continue its unspecialized master's programme in mathematics,

ii) consider the consultants' recommendations concerning part-time studies and/or a specialized MSc programme in applied probability,

iii) give serious attention to the recommendations of the consultants concerning its proposal for a master's programme in computer science.

(See recommendations 11, 29 and 37 of the consultants' report.)
See also recommendation C4, page 15.

LIST OF RECOMMENDATIONS

Recommendation C1

It is recommended that the universities give careful consideration to the comments of the consultants and plan their doctoral admissions to ensure for each of the areas a reasonable balance between the number of graduates and the employment opportunities.

It is also recommended that the universities plan for roughly stable full-time enrolments at the master's level but be prepared to adjust their sights in response to any notable change in the employment market.

It is strongly recommended that the universities examine their enrolment/graduation data to determine the underlying cause for the high ratio of enrolments to graduations and work with the discipline group to establish what action, if any, is needed (see also recommendation C3, page 11).

Recommendation C2

It is recommended that part-time study at the master's level be made available when appropriate and practicable.

Recommendation C3

It is recommended that the Mathematical Sciences Discipline Group review the enrolment-employment situation annually and make appropriate recommendations to ACAP to adjust the target objectives if this is warranted.

It is also recommended that the discipline group report to ACAP by May 31, 1977, on the seemingly high enrolment/graduation ratios, making specific recommendations if this seems appropriate.

It is also recommended that the discipline group, in addition to its normal role, undertake a study of the many recommendations of the consultants in Chapter III that deal with matters of collective concern. The group should report to ACAP before May 31, 1977, on the desirability, feasibility and, where appropriate, the implementation of the actions proposed in recommendations 38, 39, 40, 44 and 45 of the consultants' report.

Recommendation C4

It is recommended that the University of Toronto and York University report to ACAP by December 31, 1977, on progress in connection with:

i) the involvement of York faculty in the supervision of research students at the University of Toronto (see recommendation 11, page A-42),
ii) the development of a regular statistical seminar involving the collaboration of both groups (see recommendations 20 and 29, pages A-55 and A-62), and
iii) the proposed programme in computer science at York, if it is to involve collaboration with the University of Toronto (see recommendations 30 and 37, pages A-64 and A-71).

Recommendation C5

It is recommended that Carleton University and the University of Ottawa report to ACAP through the Joint Ottawa-Carleton Committee for Graduate Studies by December 31, 1977, on progress towards:

i) a cooperative programme in the field of information and systems science (see recommendations 15 and 16, pages A-47 and A-48),
ii) increased collaboration among the statisticians of the two universities (see recommendations 22 and 23, pages A-57 and A-58), and
iii) the development of a comprehensive joint programme of academic work in computer science for the Ottawa area (see recommendations 32 and 33, pages A-66 and A-67).

Recommendation C6

It is recommended that Guelph, McMaster and Waterloo universities and the University of Western Ontario discuss the possibility of collaboration in the variety of ways indicated by the consultants and report to ACAP by December 31, 1977, (see recommendations 21 and 28, pages A-56 and A-61 as well as comments in Chapter III).

Recommendation C7

It is recommended that the University of Toronto continue its graduate programmes in all four areas of the mathematical sciences (see recommendations 2, 13, 20 and 30 of the consultants' report).
See also recommendation C4, page 15.

Recommendation C8

It is recommended that the University of Waterloo continue its graduate programmes in all four areas of the mathematical sciences (see recommendations 3, 14, 21 and 31 of the consultants' report).
See also recommendation C6, page 15.

Recommendation C9

It is recommended that Carleton University:

i) continue its doctoral programmes in pure and applied mathematics and statistics with more precise definition of the fields offered in the applied area,

ii) implement its interdepartmental programme in information and systems science, after consultation with the University of Ottawa as called for in recommendation C5, and giving full consideration to the consultants' view on the role of statistics and probability in this field.

(See recommendations 4, 15, 22 and 32 of the consultants' report.)
See also recommendation C5, page 15.

Recommendation C10

It is recommended that the University of Ottawa:

i) continue its master's programme in pure mathematics, develop and submit for appraisal its proposed MA(T) programme and submit its doctoral programme in pure mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

ii) continue its master's programme in applied mathematics, develop an interdepartmental programme in mathematical economics and submit its doctoral programme in applied mathematics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

iii) submit its interdisciplinary master's programme in general systems and information sciences for appraisal, ceasing to enrol students after December 31, 1977, until a favourable appraisal has been obtained,

iv) submit its master's and doctoral programmes in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

v) defer further development of its proposed master's programme in computer science pending the results of the discussion called for in recommendation C5.

(See recommendations 5, 16, 23 and 33 of the consultants' report.)
See also recommendation C5, page 15.

Recommendation C11

It is recommended that Queen's University continue its doctoral programmes in pure and applied mathematics and statistics and continue to strengthen its master's programme in computer science. ACAP endorses the consultants' view that the proposal for a PhD programme in computer science be deferred (see recommendations 6, 17, 24 and 34 of the consultants' report).

Recommendation C12

It is recommended that McMaster University:

i) continue its graduate programmes in pure mathematics,

ii) complete the reorganization of its graduate work in statistics and submit the revised programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

iii) strengthen its faculty with respect to core subjects in computer science and continue its master's programme.

(See recommendations 7, 25 and 35 of the consultants' report.)
See also recommendation C6, page 15.

Recommendation C13

It is recommended that the University of Western Ontario:

i) continue its master's programme in pure mathematics and submit its doctoral programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,

ii) continue its graduate programmes in applied mathematics,
iii) submit for appraisal its graduate programmes in statistics, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
iv) continue its master's programme in computer science but defer implementation of its proposed PhD programme as suggested by the consultants.

(See recommendations 8, 18, 26 and 36 of the consultants' report.)
See also recommendation C6, page 15.

Recommendation C14

It is recommended that the University of Windsor:

i) continue its master's programme in pure mathematics and submit its doctoral programme for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained,
ii) continue its graduate programmes in applied mathematics,
iii) strengthen its staff in probability and statistics by the addition of two strong, research-oriented members or submit its doctoral programme in statistics for appraisal, ceasing to enrol new students after December 31, 1977, until a favourable appraisal has been obtained.

(See recommendations 9, 19 and 27 of the consultants' report.)

Recommendation C15

It is recommended that the University of Guelph continue its master's programme in statistics and consider the consultants' comments and suggestions concerning its work in pure and applied mathematics, reporting to ACAP on the results of its deliberations not later than May 31, 1977. If the decision of the university is to retain separate master's programmes in pure and applied mathematics, they should be submitted by September 30, 1977, for review by the Appraisals Committee (see recommendation 28 and pages A-39, A-50 and A-61 of the consultants' report).
See also recommendation C6, page 15.

Recommendation C16

It is recommended that Lakehead University:

i) continue its master's programme in pure mathematics and applied analysis and consider the consultants' suggestion to submit for appraisal a master's programme in pure mathematics, unrestricted in scope and offering the degree by course work or thesis,

ii) defer until 1979-80 its proposal for a programme in applied computer science in the light of the consultants' comments concerning the need for additional staff and the development of an adequate level of research activity.

(See recommendation 10 and page A-70 of the consultants' report.)

Recommendation C17

It is recommended that York University:

i) continue its unspecialized master's programme in mathematics,

ii) consider the consultants' recommendations concerning part-time studies and/or a specialized MSc programme in applied probability,

iii) give serious attention to the recommendations of the consultants concerning its proposal for a master's programme in computer science.

(See recommendations 11, 29 and 37 of the consultants' report.)
See also recommendation C4, page 15.

COMMENTS OF OCGS TO COU ON THE

ACAP REPORT ON THE MATHEMATICAL SCIENCES

ACAP and the consultants are to be congratulated on producing a report that is both clear and generally agreeable to the widely varying disciplines covered under the umbrella of the mathematical sciences.

OCGS concurs with the recommendations as set forth and would make the following comments.

Recommendation C3 which states

> It is recommended that the Mathematical Sciences Discipline Group review the enrolment-employment situation annually and make appropriate recommendations to ACAP to adjust the target objectives if this is warranted.
>
> It is also recommended that the discipline group report to ACAP by May 31, 1977, on the seemingly high enrolment/graduation ratios, making specific recommendations if this seems appropriate.
>
> It is also recommended that the discipline group, in addition to its normal role, undertake a study of the many recommendations of the consultants in Chapter III that deal with matters of collective concern. The group should report to ACAP before May 31, 1977, on the desirability, feasibility and, where appropriate the implementation of the actions proposed in recommendations 38,39, 40, 44 and 45 of the consultants' report.

is strongly supported. It is hoped that any provision for the participation of faculty from one university in the graduate programme of another would extend to qualified faculty over the system as a whole, and not just to departments with some form of graduate programme in one area of mathematics or another.

OCGS also underlines the importance of the following recommendations for regional cooperation:

C4 It is recommended that the University of Toronto and York University report to ACAP by December 31, 1977, on progress in connection with:

i) the involvement of York faculty in the supervision of research students at the University of Toronto (see recommendation 11, page A-42),
ii) the development of a regular statistical seminar involving the collaboration of both groups (see recommendations 20 and 29, pages A-55 and A-62), and
iii) the proposed programme in computer science at York, if it is to involve collaboration with the University of Toronto (see recommendations 30 and 37, pages A-64 and A-71).

C5 It is recommended that Carleton University and the University of Ottawa report to ACAP through the Joint Ottawa-Carleton Committee for Graduate Studies by December 31, 1977, on progress towards:

i) a cooperative programme in the field of information and systems science (see recommendations 15 and 16, pages A-47 and A-48),
ii) increased collaboration among the statisticians of the two universities (see recommendations 22 and 23, pages A-57 and A-58), and
iii) the development of a comprehensive joint programme of academic work in computer science for the Ottawa area (see recommendations 32 and 33, pages A-66 and A-67).

C6 It is recommended that Guelph, McMaster and Waterloo universities and the University of Western Ontario discuss the possibility of collaboration in the variety of ways indicated by the consultants and report to ACAP by December 31, 1977, (see recommendations 21 and 28, pages A-56 and A-61 as well as comments in Chapter III).

Recommendation C2 which states

> It is recommended that part-time study at the master's level be made available when appropriate and practicable.

is particularly appropriate in the more applied areas of statistics and computer science.

The recommendations calling for external appointments to supervisory committees and for more interuniversity statistics seminars may be appropriate. To encourage interuniversity exchanges in the mathematical sciences support, both moral and financial, is required. The lower level of federal research funding in mathematics when compared with the physical and biological sciences may not permit as much travelling as would be desirable.

Computer science, in a position on the boundary of mathematics, and applied science and engineering, should not be pushed into an over emphasis on either pure mathematics or straight hardware problems, but must maintain strong roots in both areas. One should not be strengthened at the expense of the other.

As is clear from the ACAP and consultants' reports, problems arise from the presence of many departments and programmes within each university, encompassing the diverse disciplines of the mathematical sciences. Each university should consider some coordinating body to catalogue and correlate interests of a mathematical nature because in many instances applied mathematics is found in departments of the social, physical, biological and engineering sciences.

It is regretted that there is no direction regarding the introduction of new master's programmes either in specific or general areas or of an interdisciplinary nature.

January 5, 1977

RESPONSE OF THE DISCIPLINE GROUP OF THE MATHEMATICAL SCIENCES
TO THE ACAP REPORT
ON THE MATHEMATICAL SCIENCES PLANNING ASSESSMENT

The Discipline Group would like to make several comments on the ACAP Report to be considered in conjunction with our earlier response to the Consultants' Report.

1. OPTIMAL NUMBER OF GRADUATE STUDENTS

We are in basic agreement with the statement that the present number of M.Sc. students is of the right order (Recommendation C1) although the suggestion that part-time studies be encouraged (Recommendation C2) could lead to a small increase in the size of master's programs.

With regard to the suggested numbers of Ph.D's per year, the Discipline Group is satisfied with the conclusions of the Report concerning Pure Mathematics and Computing Science. As is pointed out in the ACAP Report, the present enrolment figures in Applied Mathematics and Statistics appear to be compatible with the suggested number of 10 Ph.D.'s per annum in each of the two areas. The Discipline Group feels, nevertheless, that it would be unwise to adopt a figure of 10 for each of these areas for the coming years. The reasons for this are given at the bottom of page 2 and the top of page 3 in our response to the Consultants' Report. They are, briefly, that in Statistics there do not appear to be enough Ph.D's available for the positions presently available and that in the case of both Statistics and Applied Mathematics the possibilities of non-academic employment could make the figure of 10 too small in the very near future.

2. ENROLMENT/GRADUATION RATIO AND LENGTH OF PH.D. STUDY

In Recommendation C1 it is strongly recommended that the universities examine their enrolment and graduation data to determine the underlying cause for the high ratio of enrolments to graduations. In the three academic years 1972 - 1975 this ratio is 4.9, 5.9 and 4.3 respectively. It is higher for the year just past but we feel that the graduation figures are incomplete (the date of the table is June 17, 1976). We do not find these figures at all excessive. If we assume the students who go on to Ph.D. studies finish their master's degree in one year and if we also assume that a period of four to five years after the B.Sc. is appropriate for a Ph.D., this would lead to the conclusion that, without any attrition at all on the Ph.D. level, the figures should be about 3.5. If we use this figure in 1974/75 for example, this would mean that 89 students out of 310 should graduate whereas there were only 71 graduates - the difference could be accounted for by 18 students dropping out during the year. We fail to see how these figures can be interpreted as excessive. They seem to us entirely normal and desirable and we do not believe that further action on the part of the universities or the Discipline Group is appropriate.

A closely related matter is, of course, the desirable length of time for Ph.D. studies. The Consultants (second paragraph, page A-15) state that the time required for the doctoral degree should not exceed three or four years of full-time study beyond the baccalaureate under normal circumstances and this length of time appears to underline the ACAP calculations leading to the part of Recommendation C1 alluded to above. As we have already pointed out in our response to the Consultants' Report, the Discipline Group disagrees with this view and feels that a more appropriate figure for the length of Ph.D. study beyond the baccalaureate is four to five years, especially in view of the statement by the Consultants that more comprehensive requirements for graduate students and increased emphasis on quality are desirable.

3. SIZE OF GRADUATE PROGRAMS, INTER-UNIVERSITY COLLABORATION AND GRADUATE SUPERVISION

The ACAP Report supports many of the Consultants' views on these topics and we would like to refer to our reactions to them on pages 4, 5 of our response to the Consultants' Report.

4. MASTER'S DEGREE

Again we would like to refer to our statement on page 5 in our response to the Consultants' Report on this topic.

5. UNIVERSITY RECOMMENDATIONS

As already noted in the first paragraph on page 6 of our response to the Consultants' Report the Discipline Group is unhappy with the statement on page 14 of the ACAP Report on Computer Science, since it might be interpreted as implying that Computer Science should strengthen its ties with the other areas of the Mathematical Sciences at the expense of its ties with other university disciplines such as Science, Engineering and Social Sciences.

Although the Discipline Group does not wish to take issue with the requests for the reappraisal of certain graduate programs, there was some dissatisfaction expressed about the short length of time given to the universities to implement some of the recommended changes before such appraisal takes place. A motion was passed, (5 in favour, 3 against, 13 abstentions) that, in those cases in which the university feels that the allotted time is inadequate, the proposed deadline for reappraisal be changed to December 31, 1978.

There was also some discussion in the Discipline Group about the judgments rendered on Ph.D. theses at certain universities and we again refer to our statement on page 6 of our response to the Consultants' Report on this matter.

THE PRINCIPAL
AND VICE - CHANCELLOR

Queen's University
Kingston Canada
K7L 3N6

8 December 1976

Dr. H. H. Yates
Executive Vice-Chairman, OCGS
Council of Ontario Universities
130 St. George Street, Suite 8039
Toronto, Ontario M5S 2T4

Dear Dr. Yates:

I am writing to state that Queen's University is satisfied with the ACAP Report on the Mathematical Sciences Planning Assessment, and does not wish to submit any comments except its general approval of the Report as related to Queen's University.

There is no objection to the publication of this reply.

Yours sincerely,

Ronald L. Watts
Principal and Vice-Chancellor

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto, Canada M5S 1A1

December 13, 1976

Dr. H.H. Yates
Executive Vice-Chairman
Ontario Council on Graduate Studies
Robarts Library, 8th Floor (Suite 8039)
130 St. George St.
Toronto, Ontario

Dear Dr. Yates:

I am writing to say that the University of Toronto does not wish to make any further comment on the ACAP report on the Mathematical Sciences for COU's consideration.

I should be glad, however, if you could convey to ACAP, and to the consultants, the University's thanks for a report whose constructive criticism has been very helpful to us. Without going into detail, we have now found an organizational solution which will greatly aid our programs in statistics; a review of applied mathematics is also under way. Universities (even this one!) occasionally need such an external review to spur change; I am glad to be able to say that ACAP's confidence in this University's willingness and ability to deal with the issues raised by the consultants has not been misplaced.

Yours sincerely,

James M. Ham

James M. Ham
Dean

JMH/ss

UNIVERSITY OF WINDSOR
WINDSOR, ONTARIO N9B 3P4
TELEPHONE: AREA CODE 519
253-4232

February 1, 1977

Dr. H. H. Yates
Executive Vice-Chairman
Ontario Council on Graduate Studies
130 St. George Street
Suite 8039
Toronto, Ontario
M5S 2T4

Dear Dr. Yates:

I write in reply to recommendation C14, iii). of the Report to COU on the Mathematical Sciences.

It is recommended that we strengthen our staff in probability and statistics by the addition of two strong, research-oriented members or submit our doctoral program in statistics for appraisal, ceasing to enrol new students after December 31st, 1977, until a favourable appraisal has been obtained.

While the consultants were already engaged in preparation of their Report we had reached a similar conclusion, and had advertised in the Fall of 1975 for the first of these appointments. We were able to make a suitable appointment in early 1976, and the appointee is now on staff.

Shortly thereafter another vacancy occurred in the Department of Mathematics, and it was agreed that it would be assigned as a second, additional appointment in statistics, and it is currently held by a scholar of repute and much teaching experience, whom we hope will be willing to join our staff with full tenure, in due course.

As the forgoing would indicate the University of Windsor had accepted, in advance of the consultants' recommendation the need for two, research-oriented appointments, and has already provided them. I would accordingly suggest that it should be noted that the condition now specified in the Report to COU on the Mathematical Sciences, in respect to our program in statistics, has been fully met.

Yours sincerely,

J. F. Leddy
President

JFL:sp

APPENDIX A

PLANNING ASSESSMENT OF THE MATHEMATICAL SCIENCES IN ONTARIO

G. Birkhoff
D. R. Cox
A. H. Morrish

April 1976

The University of Manitoba

Department of Physics
Winnipeg, Manitoba R3T 2N2

April 27, 1976

Dr. H. H. Yates
Advisory Committee on Academic Planning
Appraisals Committee
Ontario Council on Graduate Studies
130 St. George Street, Suite 8039
Toronto, Ontario
M5S 2T4

Dear Dr. Yates:

You will find our report on the mathematical sciences enclosed. We wish to express our appreciation to the mathematics departments of the Ontario universities for their careful attention to the preparation of the various documents and forms required for an ACAP assessment of graduate programs. We are indebted to Miss S. Cale who reduced the vast amount of data to a form suitable for the tables and figures. She also arranged the mechanics of our visits to the universities with great efficiency. We also thank you, and your predecessor, Dr. M. A. Preston, for information and advice.

Although we have attempted to produce a report free of errors, some may occur. However, if there are any we do accept full responsibility for them.

We hope this report is acceptable and useful.

Yours truly,

Garrett Birkhoff

G. Birkhoff,

D. R. Cox

D. R. Cox, and

A. H. Morrish

A. H. Morrish
Consultants

AHM/gma

Enc.

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PLANNING ASSESSMENT OF THE MATHEMATICAL SCIENCES IN ONTARIO

CHAPTER I

PRELIMINARIES

1. Introduction

This report is concerned with the graduate programmes in the mathematical sciences offered at the Ontario universities. It was commissioned by the Advisory Committee on Academic Planning (ACAP), a committee of the Ontario Council on Graduate Studies (OCGS) which in turn is an affiliate of the Council of Ontario Universities (COU). The terms of reference are reproduced in Appendix I. It is useful to elaborate on some aspects of these terms, and to indicate how they were interpreted and implemented; this is done in section I-2.

The level of activity in the mathematical sciences at present is discussed in section I-3, and compared with that in Canada as a whole, and in other countries with similar traditions. Some remarks on the degree of activity and relative quality will be made. The role of the master's and the doctoral programmes will be discussed in section I-4. Next, the students, their preparation and distribution between areas, and universities, will be considered in section I-5. The current employment prospects and limitations on enrolment will be interrelated in section I-6. Chapter I will then be concluded by some general remarks in section I-7.

Chapter II is concerned with detailed reports for different areas of mathematics and for different universities. Chapter III concludes the main body of the report, and presents our general conclusions and recommendations.

Fourteen disciplines have been assessed by consultants appointed by ACAP. The format of the reports presenting these assessments, the nature of the arguments used, and the degree of acceptance and usefulness have influenced, positively or negatively, this report on the mathematical sciences. Especial mention should be made of the COU Report 11B on Electrical Engineering (1974), and of the COU Report 14 on Physics and Astronomy (1974).

During the course of the present investigation, Background Study 38, sponsored by the Science Council of Canada, entitled *Mathematical Sciences in Canada*, by A. J. Coleman, G. D. Edwards and K. P. Beltzner, became available. Their terms of reference were broad; they were to consider the kind and extent of the usage of mathematics in Canada, to evaluate the present types of research, to estimate present and future manpower supplies and needs, to examine training methods, as well as other matters. The influences of mathematics at all levels, including the interactions of mathematicians and users of mathematics were described by the suggestive phrase "mathematical ecosystem". This ambitious and imaginative report can be read with profit by all interested in the mathematical sciences. Its relationship to the present report is however peripheral, and it will be referred to only occasionally.

Other sources of information used as general background tended to be more specialized. Examples are Statistics Canada, and the De Lury report on statistics at the University of Toronto. Any use of such literature will be noted at the pertinent part of the text.

2. Procedures

The mathematical sciences have undergone great growth all over the world in the past twenty years. At one time, it was primarily physics, chemistry, and engineering students who needed a knowledge of mathematics for use in their subject. Nowadays, the list of users is vast, and includes most disciplines in the biological sciences and the social sciences, and, although to a lesser degree, even some students in the humanities. Computer science, which after some hesitation has properly settled into a mathematics setting, is a major new development. A large faculty in mathematical sciences is required just to satisfy undergraduate teaching needs. In addition, there have been major expansion and development at the research level in most branches of mathematics, which are at least comparable to those that have occurred in several other subjects in the past two decades. In pure mathematics the growth has been particularly great; an emphasis on abstractness has developed since World War II which however, now seems to have passed its peak. The range of applications of mathematics has also greatly increased in the past fifteen years; this expansion has important implications not only for the intellectual vigor of the subject, but also for the number of employment prospects.

The end result is that the number of mathematicians on university staffs is much larger than for many other traditional disciplines, such as chemistry or physics. Indeed, at many universities the mathematics personnel comprises close to 40% of the total in a faculty of science. An even greater variant is to be found in Ontario at the University of Waterloo, where a faculty of mathematics exists, and which is one of the largest faculties on that campus.

From the outset, it must have been clear that a planning assessment for mathematical sciences in the Ontario universities was beset with procedural problems. It was decided by ACAP, in consultation with its mathematics discipline committee, to divide the mathematical sciences into four major areas, namely,

(1) pure mathematics
(2) applied mathematics
(3) statistics, and
(4) computer science.

This choice has at least the merit of corresponding to the departmental structure employed at some universities, both within Canada, and abroad.

There are, however, anomalies. In Ontario there exists only one department with the name 'pure' mathematics', and only one called 'statistics', although there is one 'institute of applied statistics'. One department named 'applied mathematics' is primarily concerned with statistics and computer science.

These four areas have been further subdivided into fields; they are listed in Table I. The fields are much more arbitrary in nature, and are certainly not mutually exclusive, either as to area or as to field, for example: probability theory, listed under statistics, could also be assigned to pure mathematics; applied analysis, listed under applied mathematics, exists also as a form of pure mathematics in some universities; and computer science often includes a good deal of numerical analysis. Even more troublesome from the point of view of an assessment, is the mathematical component in other departments or faculties. Examples are applied mathematics in the areas of physics, chemistry, engineering, and economics, and statistics in a host of other departments.

It is important to note that some fields that may be classed as mathematics are not explicitly identified in Table I. Examples are actuarial science, business mathematics and accountancy, and operations research. Such fields could of course be listed as 'other' in Table I.

ACAP decided to appoint eight advisors, and assign two to each area (see terms of reference, Appendix I). The advisors chosen were:

(1) Pure Mathematics: W. A. J. Luxemburg
N. S. Mendelsohn

(2) Applied Mathematics: I. N. Sneddon
M. Wyman

(3) Statistics: D. R. Brillinger
W. H. Kruskal

(4) Computer Science: J. E. Hopcroft
J. M. Kennedy

In addition, ACAP appointed three consultants, two of whom were to be mathematicians. Those chosen were:

G. Birkhoff
D. R. Cox
A. H. Morrish

The mathematical science departments of the Ontario universities involved supplied extensive data on forms prepared by ACAP, together with curriculum vitae of the faculty members, as per instruction C6 of Appendix I. In addition, and of major importance, each university supplied a statement of future plans, in detail for the period 1975-80, and in outline for 1980-85 (see clause C7). Each university president also issued a statement concerning the university's plans for graduate work in the mathematical

TABLE I

MATHEMATICAL SCIENCES IN ONTARIO

AREAS AND FIELDS OF MASTER'S AND DOCTORAL WORK

(determined by ACAP in consultation with the discipline group)

1. Pure Mathematics

   Logic and Foundation
   Number Theory and Algebra
   Topology and Geometry
   Discrete Mathematics
   Real and Complex Analysis
   Functional Analysis
   Other (Please Specify)
   Unspecialized

2. Applied Mathematics

   Classical Applied Mathematics
   Mathematical Physics
   Modern Applied Mathematics
   Applied Analysis
   Other (Please Specify)
   Unspecialized

3. Statistics

   Mathematical Statistics
   Applied Statistics
   Probability Theory
   Applied Probability
   Other (Please Specify)
   Unspecialized

4. Computer Science

   Mathematical Software
   Programming Languages
   Software Systems
   Theory of Computation
   Data Management
   Artificial Intelligence
   Computer Architecture
   Other, including applications (Please specify)
   Unspecialized

sciences (see clause C8). Copies of this material, which consisted of several hundred pages, were given to the advisors and consultants.

Eleven Ontario universities offer graduate programmes in mathematics. The areas and degrees offered (doctoral and/or master's) are listed in Table II. It should be noted that some programmes are proposed for the future, and are in various stages of preparation at this time.

During the period June to September, 1975, some or all of the advisors and consultants visited these universities, as appropriate for the areas and degrees offered. These visits were very informative, and significantly supplemented the written data available. It is a pleasure to thank the members of the universities for their cooperation and many courtesies during the course of the visits by the advisors and consultants.

The reporting duties of the advisors are listed under section E in the terms of reference (Appendix I). In brief, the advisors were to submit an area report for each university, if appropriate, and to discuss the subjects listed in clause E2. After discussions between the advisors and the consultants, it was decided that each individual university report should include a general section that was common to all reports for a given area. These reports were completed during the autumn of 1975, and submitted to ACAP. Each report was sent to the university concerned. The universities, in turn, prepared comments, sometimes including rebuttals, on the contents of the advisors' reports. These comments were forwarded to the consultants by ACAP about the middle of December, 1975. The consultants obtained informally the reaction of the advisors to the comments by the universities.

Although exchanges of views between the advisors and consultants occurred during the preparation of the advisors' reports, it was inevitable that the differences in viewpoints would lead to a dispersion in treatment. Further, the nature of the reports for different universities elicited varying degrees of acceptance or rejection from the universities concerned. The consultants have felt it was their task to develop some greater degree of consistency between the area reports, and to render judgements on some controversial matters. The advisors' reports together with the universities' responses have formed the major base for the present report. However, it should be made clear that the consultants take full responsibility for any and all conclusions and recommendations in this report. The specific terms of reference for the consultants' report are listed in section F (Appendix I). The rest of this report will develop the analysis required by clause F2.

3. Scope of the mathematical sciences in Ontario universities

The range of fields in mathematics covered to some extent by graduate programmes in the Ontario universities has already been indicated by the ACAP classification in Table I. Inextricably bound

TABLE II

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

GRADUATE PROGRAMMES BY UNIVERSITY

(a doctoral programme implies there is also a master's programme in an area)

University	Pure	Applied	Statistics	Computer Science
Carleton	PhD	PhD	PhD	PhD*
Guelph	MSc	MSc	MSc	
Lakehead	MA/MSc			proposed MSc
McMaster	PhD		MSc	MSc
Ottawa	PhD	PhD	PhD	proposed MSc
Queen's	PhD	PhD	PhD	MSc
Toronto	PhD	PhD	PhD	PhD
Waterloo	PhD	PhD	PhD	PhD
Western	PhD	PhD	PhD	MSc
Windsor	PhD	PhD	PhD	
York	MA**		MA**	proposed MSc

*Given by the Department of Systems Engineering. A new interdepartmental MSc programme in Information and Systems Science (Departments of Mathematics and Systems Engineering) has been favourably appraised.

**The MA at York is unspecialized.

to this topic is the size and distribution of the mathematics faculty. Although a detailed discussion will be presented in Chapter II, it is useful to give now some overview of the picture in Ontario that will help to set the tone for the report.

The distribution of mathematicians over the four areas is given in Table IIIa for each of the past five years. The total numbers of mathematicians for all Ontario universities are given by rank in Table IIIb. Over this time scale, the growth has been slow.

A breakdown between fields is available. We have felt that such a distribution is of less value, partly because many mathematicians divide their time between more than one field, and because the situation is not and should not be static. Also, meaningful work in some fields requires activity in related fields. Anyway, the boundaries between many fields are fuzzy. Instead of presenting details, comments will be made in Chapters II and III on fields where over or under supply exists to the extent that the matter is important.

In section I-2, mention was made that some fields are covered in other than mathematics departments. We did have the opportunity to meet with some staff in other cognate departments, but not systematically and the amount of information obtained was at best fragmentary. We therefore generally exclude an assessment of mathematics research outside of mathematics departments. However, at appropriate parts of the text, a few remarks will be made on such work.

Statistical data on quality are difficult to generate, primarily because of the lack of a suitable scale of measurement. It is useful to consider peripheral but related data. Figure I shows the age distributions for the faculty; Table IV gives the same data by area. The faculty tends to be young, with a large preponderance in the 30-45 age group. This distribution is not restricted to the mathematical sciences; a similar one is to be found for almost all departments in all North American universities. It is the result of the large expansion in post-secondary education that occurred starting in about 1955 and increased further just after Sputnik. Such an expansion had never occurred before in the history of these universities, and further, there is no possibility that it can recur in the next two or three decades at least. This age distribution will therefore have profound implications for the universities for a long time to come. There will be a lack of new appointments, and difficulties will be incurred in the development of new fields.

Figure II indicates the number of faculty publishing in refereed journals (1972-1975). Clearly, the faculty is respectably active at all ages. The average and total NRC grant funds awarded by institution are displayed in Figure III. We have made some independent comparisons and find that the size of the NRC grant does correlate well with our judgement of the quality of the research of the grantee.

In 1974, the population of Ontario was 8.03 million compared to 22.31 million for Canada, that is, 36% of the total. The Ontario

TABLE IIIa

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

NUMBERS OF FULL-TIME FACULTY ACTIVE IN GRADUATE PROGRAMMES BY AREA*

	1970-71	1971-72	1972-73	1973-74	1974-75
Pure	230	242	253	263	264
Applied	130	130	134	142	159
Statistics	63	71	83	85	85
Computer Science	94	107	109	118	131

*Any individual working in more than one area is counted more than once.

TABLE IIIb

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

NUMBERS OF FACULTY BY RANK (STATISTICS CANADA)*

	1971-72	1972-73	1973-74	1974-75
Full Professors	147	159	156	165
Associate Professors	192	201	237	240
Assistant Professors	234	240	216	216
Total	573	600	609	621

*All Ontario universities.

FIGURE I

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

AGE DISTRIBUTION OF FACULTY ACTIVE IN GRADUATE PROGRAMMES - ALL AREAS

(as of December 31, 1975 - no double counting)

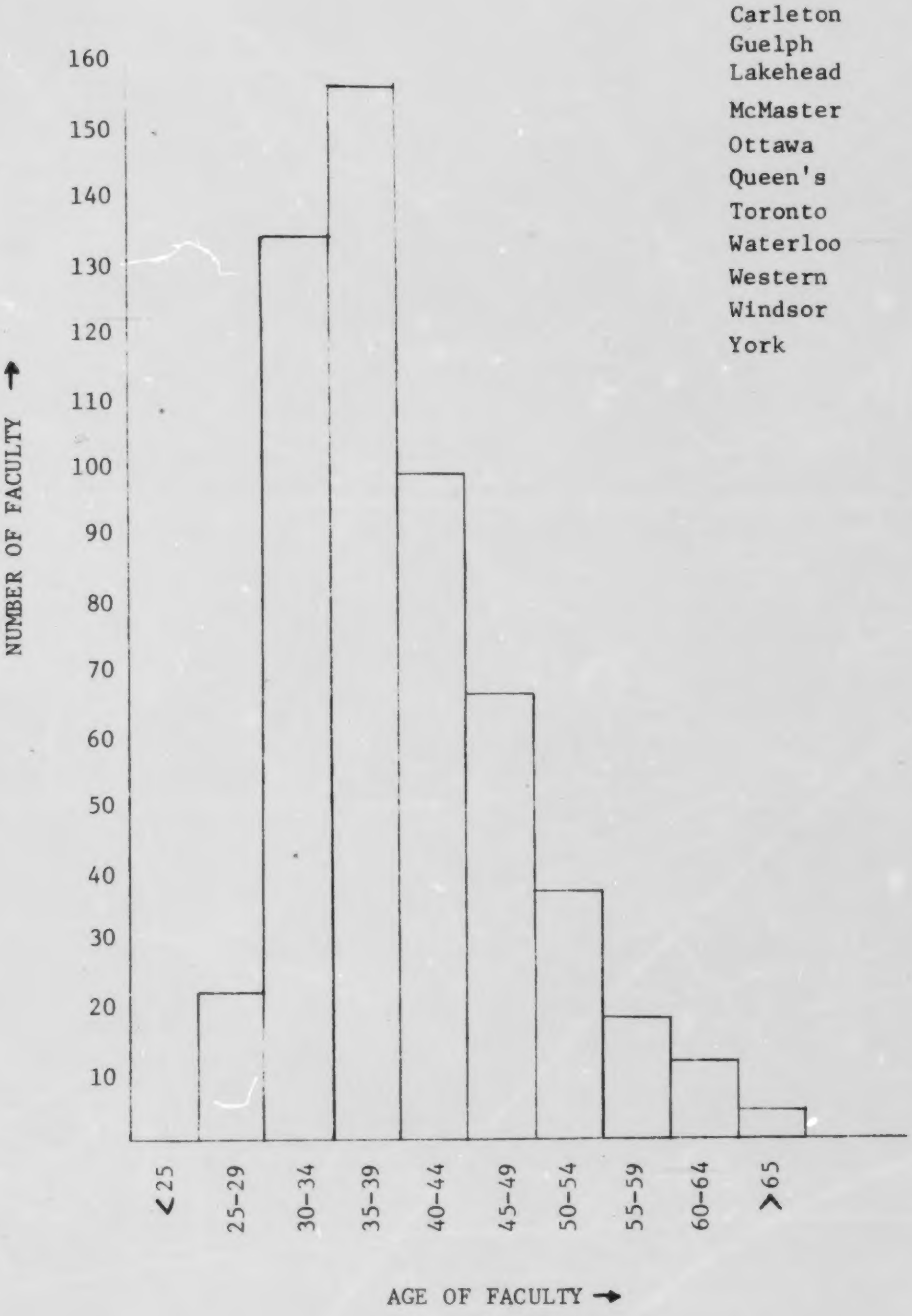

TABLE IV

AGE DISTRIBUTION OF FACULTY ACTIVE IN GRADUATE PROGRAMMES BY AREA*

(as of December 31, 1975)

AGE AREA	25-9	30-4	35-9	40-4	45-9	50-4	55-9	60-4	65 +	Total
PURE	5	66	69	42	36	13	10	7	3	251
APPLIED	6	22	51	27	19	12	4	3		144
STATISTICS	5	23	28	20	10	11	4	3	1	105
COMPUTER SCIENCE	10	42	36	20	15	10	1			134
TOTAL	26	153	184	109	80	46	19	13	4	634

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*Carleton, Guelph, Lakehead, McMaster, Ottawa, Queen's, Toronto, Waterloo, Western Ontario, Windsor and York.
Any individual working in more than one area is counted more than once.

FIGURE II

MATHEMATICAL SCIENCES ON ONTARIO
FACULTY PUBLISHING RECORD IN REFEREED JOURNALS
(1972-1975)

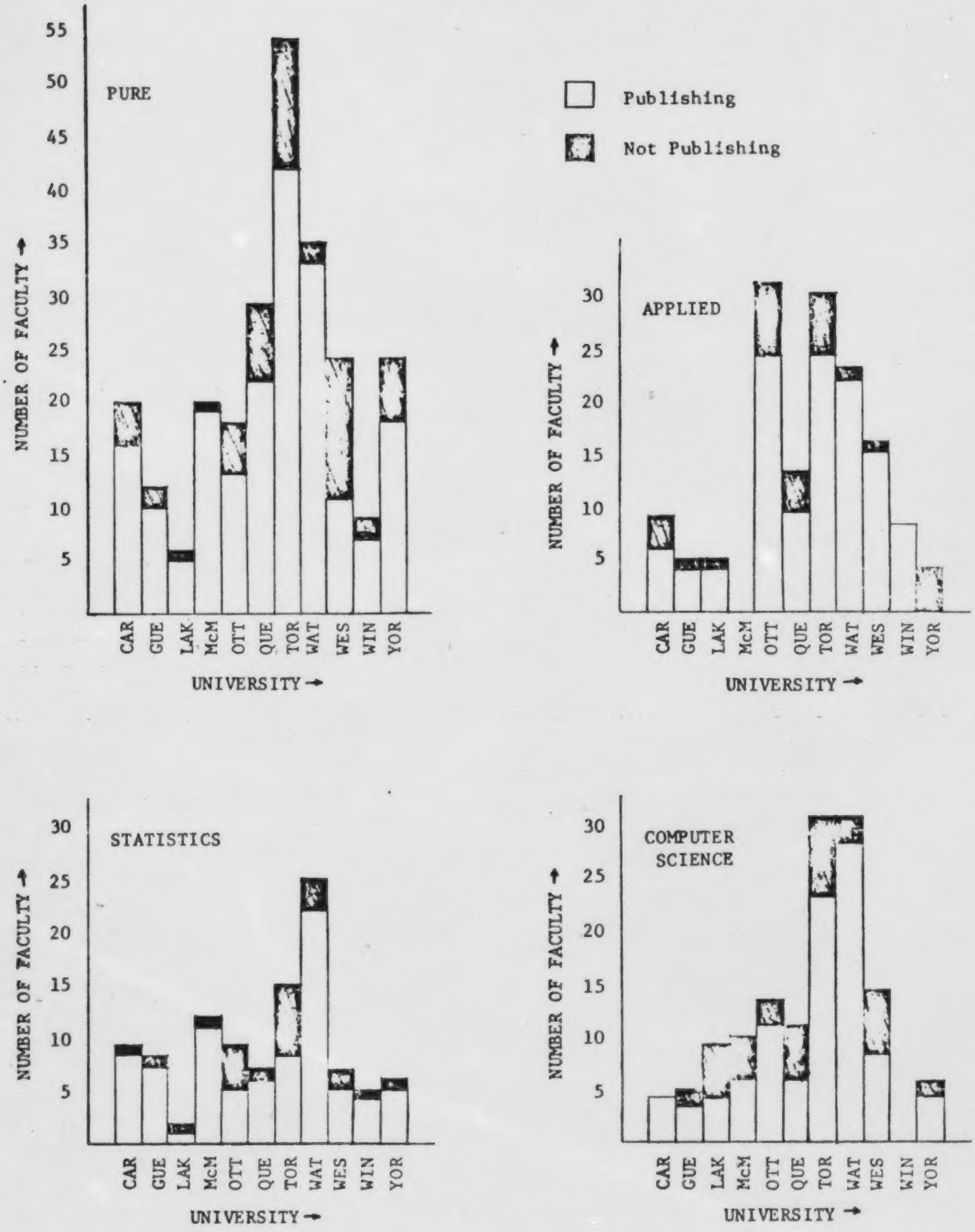
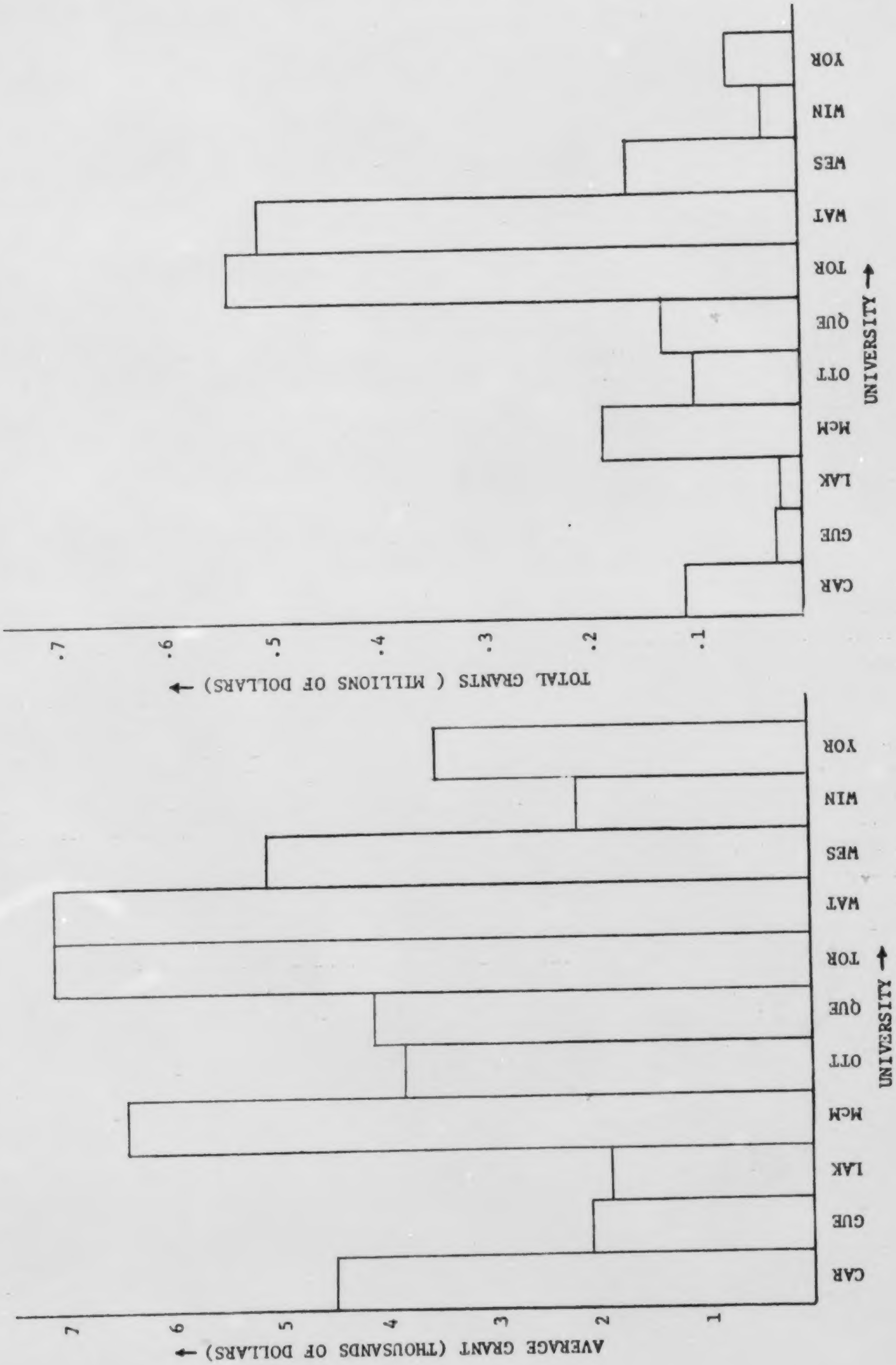


FIGURE III

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

NRC GRANTS



universities had 40% of the total faculty (all subjects) in Canada for 1971. The corresponding figure for the mathematical sciences was not available, but it appears that it exceeded 40%. These statistics should not be a surprise since Ontario is one of the oldest and most highly industrialized of the provinces, and has a long tradition in education. In our opinion, the breadth of activity and quality in the mathematical sciences in Ontario is superior to that in any other province of Canada.

It should be kept in mind that these statements do not imply a uniform distribution in mathematical talent over the Ontario universities, and indeed, it is just the reverse; this is a subject for discussion in Chapters II and III. Nevertheless, it is appropriate to state now that in many of the fields and each of the areas at least one Ontario university is to be rated in the top two or three in Canada (see clause E2g, Appendix I). Such a rating is not necessarily too significant, since, for example, there are only about four or five universities in Canada that currently offer a PhD in computer science.

In most fields, the level of mathematical research in any Ontario university does not rank in the same class as the small number of best centres in the world. An exception is computer science at the University of Toronto, which rates in the first half-dozen in North America. Even here, there are two caveats: (1) many US universities do not offer a PhD in computer science, and (2) many, if not most, of the leading participants in this area do not hold university appointments; they work in the US computer corporations, which, as a group, are the world leaders.

Another exception is the presence of a number of individuals with international reputations, some of whom are among the world leaders in at least some special field. We hope we create no ill will by mentioning classical geometry, foundations of statistical inference, combinatorics, and some aspects of algebra.

We turn now to consider the scope of coverage. Most fields of mathematics are covered to a reasonably complete degree in some Ontario university or other. There are some areas that are not, including probability, algebraic geometry, artificial intelligence, computer graphics, modelling of plasmas, solid mechanics, and control theory; they will be discussed in greater detail in Chapters II and III.

A more difficult question concerns coverage of topics in fields that are not fashionable and have little relevance at this time. Even in subjects as important as mathematical physics and functional analysis there is some danger of excessive emphasis on aspects currently outside the main stream of development. Of course, excellence in such fields can always be defended.

4. Role of the master's and doctoral programmes

Some remarks have been made in the two previous sections on the areas and fields of research in the mathematical sciences at eleven Ontario universities. The assessment of research as such is not one of our tasks. However, it goes almost without saying that the basis for any strong graduate programme must be the research abilities, interests, and activities of the faculty. We feel very strongly that the converse does not follow.

At several of the universities it was argued that a graduate programme was essential for the existence of a healthy research activity. We do agree that the presence of graduate students can add stimulation and even excitement to the atmosphere, can increase the volume of research, and can provide the opportunity to keep up to date through the mechanism of teaching graduate courses and through discussions with students. However, we do not believe that research should be viewed as the outgrowth of a graduate programme; instead graduate programmes should develop as the natural consequence of the faculty's research. There is no excuse for the faculty not engaging in research just because no graduate students are enrolled, especially not in the mathematical sciences.

Three possible paths to the master's degree in mathematical science exist at one or another of the Ontario universities. One requires only successful completion of a number of formal lecture or reading courses, a second involves courses plus a project paper, and the third, courses plus a thesis. The difference between a project paper and a thesis is in the amount of time required, the depth of coverage, and the originality. The master's programme has various purposes. It may be deliberately terminal in nature, and provide further training beyond the baccalaureate in depth and breadth. Sometimes it is a mechanism whereby students get training in fields of mathematics that will aid them to gain employment; for example, computer science and statistics. For some students, deficiencies can be made up. For others, the master's acts as a testing ground for further work; a device that is useful both to the student and to the university. For a very few students, with clearly identified ability and a strong undergraduate background in mathematics, the master's programme probably serves little purpose; direct entry to the doctoral programme is advisable. In any event, the advisors and consultants are pleased that most departments agree that full-time study for the master's degree should not normally exceed twelve months for well qualified students.

It seems universally acknowledged that the essential purpose of the PhD is to provide training in research. There is less agreement on the best methods to achieve this goal. However, clearly the thesis is the major component; normally at least part should be published in a journal with recognized standards. Usually the PhD also requires course work, although this should not always be obligatory. In many US and UK universities, students with good preparation often take no courses formally, although they may audit some lectures and be involved in seminars.

Some kind of qualifying examination must be used to see that a student has reached a reasonable level of knowledge and understanding of some basic fields of mathematics. It is possible to become over specialized in mathematics these days. In the present world situation, it is important that a doctoral student have as wide a range of knowledge in several fields of mathematics as is consistent with time limitations.

The mechanism whereby a student gets led into a research project depends on many factors, including the personalities involved. However, it is very helpful if the beginning graduate student interacts with at least competent and if possible outstanding mature mathematicians, as well as with eager fellow graduate students and post-doctoral fellows in various stages of development. The time required for the doctoral degree should not exceed three or four years of full-time study beyond the baccalaureate under normal circumstances. In exceptional circumstances, five years may be permissible, but more than five years should not be tolerated, except on medical grounds.

5. Profiles of the graduate students

A most important element of this report concerns the graduate students themselves. One of the more significant aspects of the visitations by the advisors and the consultants to the Ontario universities has been the interviews with some of the graduate students in the mathematical sciences. Impressions, perhaps transitory and sometimes even inaccurate, were gained of the morale, enthusiasm, air of stimulation, and level of training prevailing in a given department. Inevitably, some of these feelings have found translation into various parts of the text of this report.

The total numbers of students in master's and doctoral programmes in 1974-75 are plotted by university in Figure IVb. In addition, the total faculty and number of course registrations, both undergraduate and graduate, are given in Figure IVa to assist in normalization. The numbers of master's and doctoral degrees granted in the past five years are also tabulated. All areas were combined to form this diagram. Data for Ontario, Canada, the US and Great Britain are listed for comparison purposes in Table V.

A few aspects of the data in Figure IV and Table V should be noted. The number of PhDs generated in all areas is about 60 per year. 1970 represents a low, and for the other four years the average is about 72 PhDs per year. Ontario produced more than 50% of the graduate degrees in Canada for 1970-74; it has enrolled more than half the doctoral students, but only 38% of the master's students. It was mentioned in section I-3 that Ontario had about 35% of Canada's population. Even allowing for dropouts and part-time students, the figures from Figure IV imply that the time taken to obtain either a master's or a doctoral degree is longer than that we recommended (section I-4).

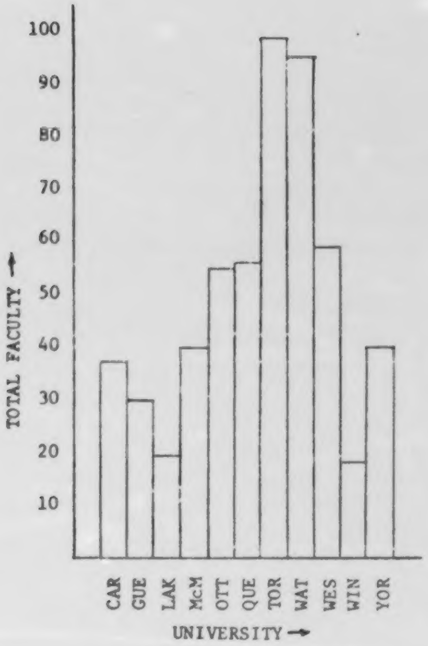
FIGURE IV a

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)

TOTAL FACULTY

and

TOTAL COURSE REGISTRATIONS



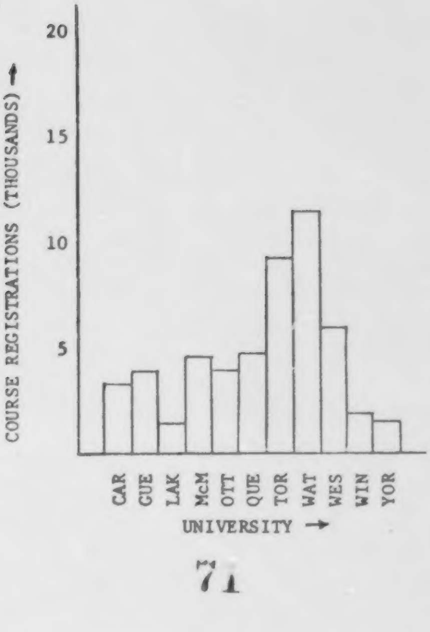


FIGURE IV b

MATHEMATICAL SCIENCES IN ONTARIO (ALL AREAS)

GRADUATE STUDENT ENROLMENTS (1974-75)

and

DEGREES GRANTED (1970-71 to 1974-75)

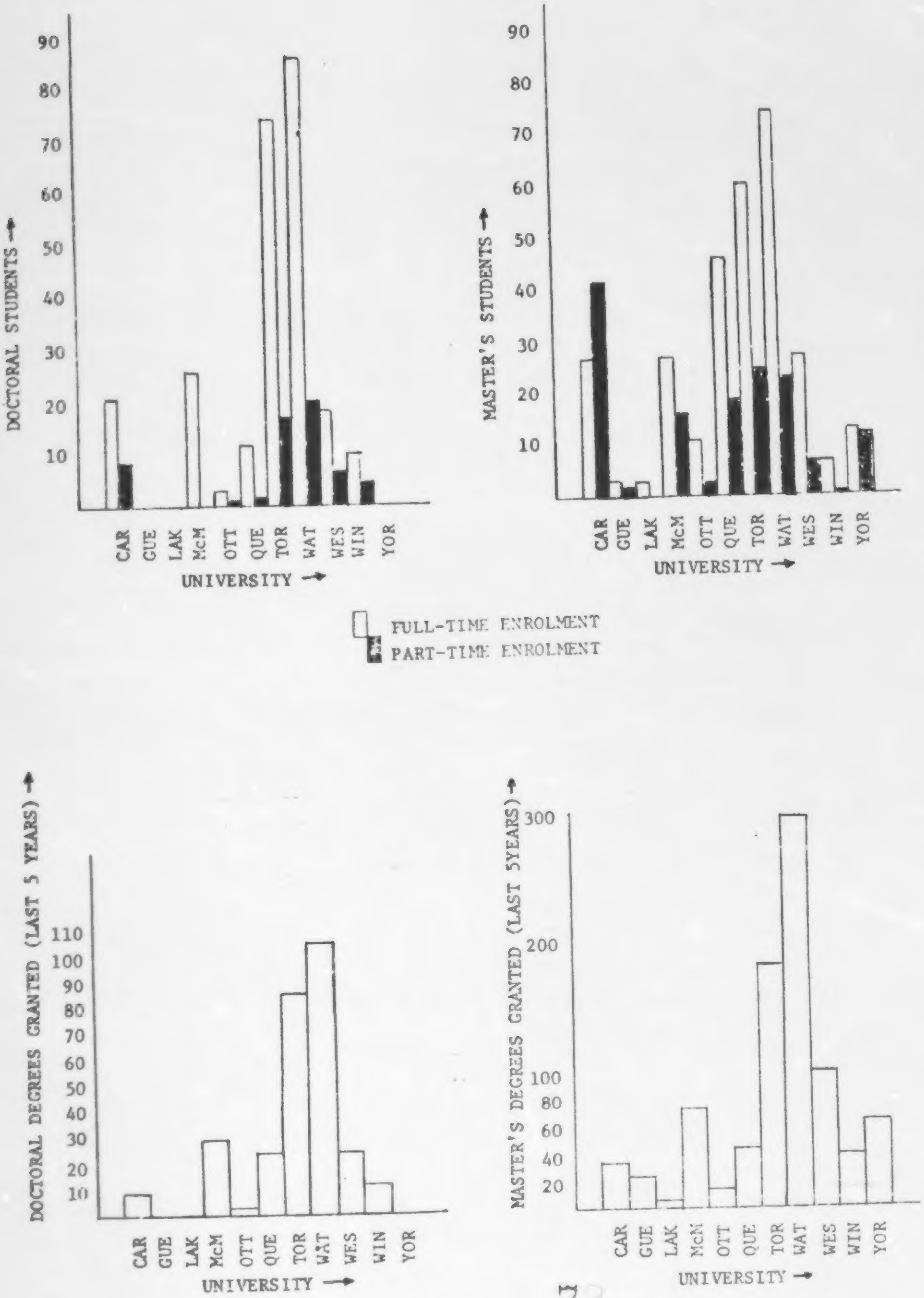


TABLE V

MATHEMATICAL SCIENCES (APPROXIMATELY 1974)

COMPARATIVE FIGURES* FOR ONTARIO, CANADA, US AND UK

	ONTARIO	CANADA	US	UK
Population	8×10^6	22×10^6	211×10^6	51×10^6
PhD Awarded (Mathematical Sciences)	70	110	1300	270
per million population	8.8	5.0	6.1	5.3
PhD Awarded (All Subjects)	910	1800	34000	4500
per million population	114	82	161	88
Faculty (Mathematical Sciences)	630	N/A	13000	1900
per million population	78	-	61	37
Faculty (All Subjects)	9000	23000	N/A	36000
per million population	1125	1045	-	706

*The figures are approximate and some of the definitions are not identical between different jurisdictions.

The numbers of Canadian and of foreign PhD graduates in each area are given by university in Figure V. Some students with landed immigrant visas undoubtedly had reasons for being in Canada other than to enrol in graduate programmes in mathematics. However, it is probably safe to assume that the great majority came as the result of offers from Ontario universities. The mix is variable, but at the doctoral level there are as many or more from foreign countries as from Canada. The Canadians dominate at the master's level, which is not surprising. It appears that this pattern is similar to that for other disciplines in Ontario and in Canada as a whole. The large component of the graduate student body from outside Canada has few parallels.

The preparation and the quality of the graduate student body is less easy to evaluate. Generally, we have received the impression that the entrance requirements for foreign or Canadian students are respectable. We were pleased to find that the graduate dean's office in some universities exercised considerable control on admissions. Although we do not believe in arbitrariness, such control can dampen departmental excesses which may from time to time appear.

One measure of quality may be the percentage of students who hold NRC fellowships. This information is displayed in Figure VI. Recent NRC regulations governing the award of fellowships will make it more difficult for a foreign student, even one with a landed immigrant visa, to win a fellowship, at least for more than a two year period. Therefore, this quality factor will be biased in favor of those departments with the largest Canadian enrolments. Nevertheless, we believe Figure VI to be significant and interesting.

Is there a critical minimum size for a graduate programme in mathematical science? The interaction with other students can be as important as that with the faculty. However, the numbers needed are probably not large. When there are fifty graduate students around, close communications are not usually within groups of more than five to ten fellow students. We feel that a graduate programme can be successful with as few as five students enrolled. Indeed, a friendly atmosphere and feeling of belonging may be generated which may be absent in a larger graduate school. Enrolments under five must create difficulties, if only in the offering of a reasonable selection of graduate courses. Even here, however, we do not feel we should take an unequivocal position. Personalities vary; some individuals seem to be unable to work other than in complete isolation. Some late bloomers, but with great ultimate potential, may flourish best in a very small graduate school (see also section III-3).

6. Employment opportunities and limitations on enrolments

A major factor determining the maximum number of graduate students enrolled must be the employment prospects. From Table IV, it is clear

FIGURE V

MATHEMATICAL SCIENCES IN ONTARIO

NUMBER OF PhDs GRANTED AND CITIZENSHIP STATUS OF GRADUATES
(1970-71 to 1974-75)

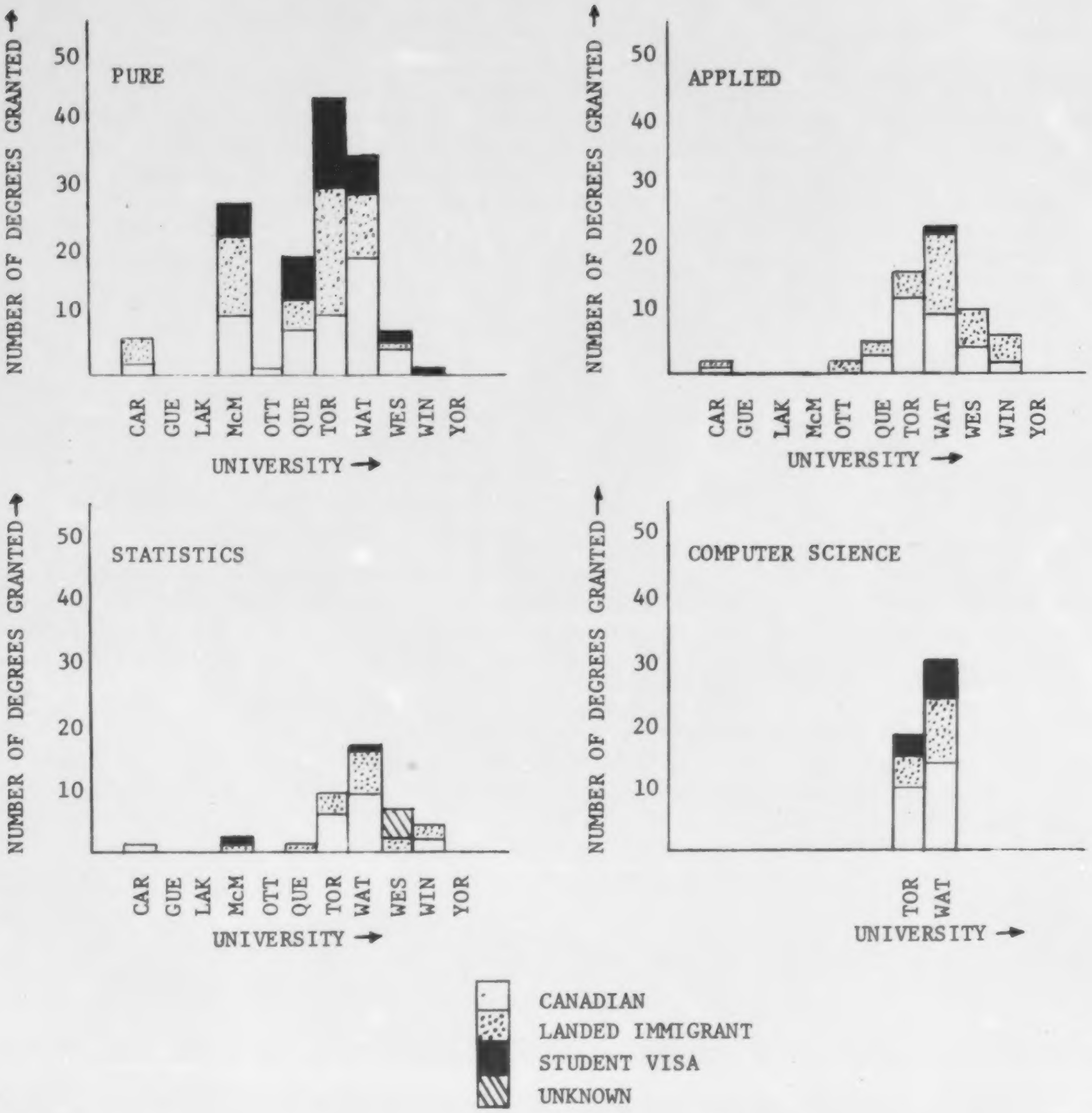
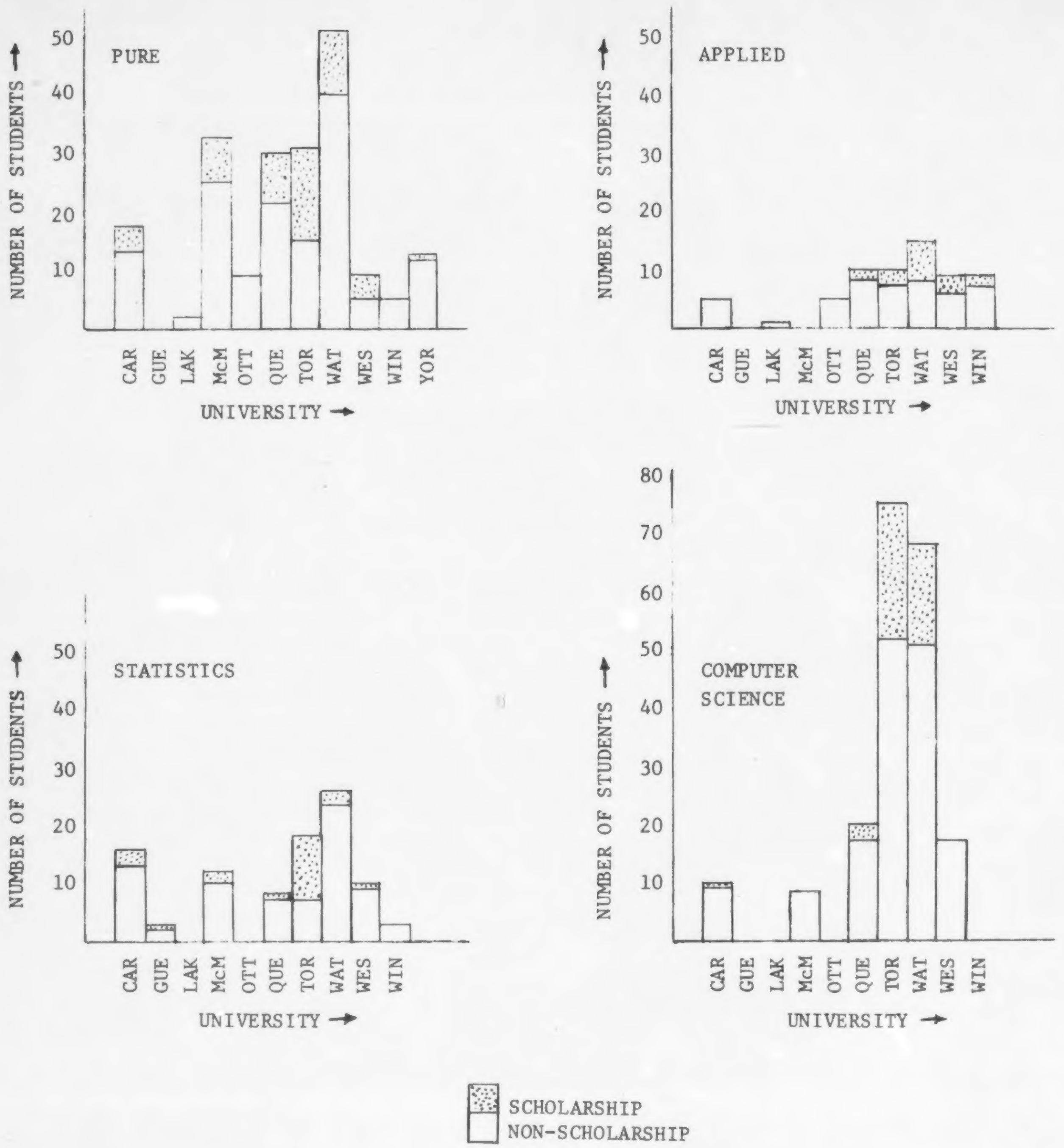


FIGURE VI

MATHEMATICAL SCIENCES IN ONTARIO (1974-75)
PROPORTION OF MATHEMATICS GRADUATE STUDENTS
HOLDING NRC SCHOLARSHIPS



that there will be few retirements in the mathematical sciences for 1975-80, and not many more for 1980-85, even if early retirement schemes are introduced. Some faculty will resign, either to accept positions outside Ontario, or to accept non-university jobs (most likely for statisticians and computer scientists) or for medical reasons. Mobility between universities in the mathematical sciences is low at the present time, and may even decrease in the next decade, so that attrition of this sort is not likely to be great.

Whether or not new positions are created will depend primarily on the overall student enrolment. Some pertinent data on this matter are given in Appendix III of the COU Report on Physics and Astronomy. The projected population of the 18-24 age group will still rise for 1975-80, but will peak at about 1982 and thereafter decrease. The only factors that could change these predictions are massive immigration on the positive side and some catastrophe on the negative side. The fraction of this age group that will enter a university depends on sex and geography, but for Canada in 1974 it averaged about 11%. It is unclear what fraction of these students will elect undergraduate programmes in the mathematical sciences, but we feel it is reasonable to expect that this discipline will hold its own. Therefore, there will probably be some small growth in the faculty size during 1975-80; certainly we found, in our travels, that some new positions had been created for 1976.

In view of all these factors, it is difficult to see how there could be more than fifty appointments for 1975-80, or an average of ten per year, in the Ontario universities. Prospects are unlikely to improve for 1980-85. It should be emphasized that there may well be fewer than ten positions per year coming open in the next decade.

There are of course opportunities for employment outside the Ontario universities, especially for statisticians and computer scientists. There has been a demand exceeding the supply for computer scientists at least, both in government and in industry. However, these jobs tend to be in 'applied' computing, and at some point in the foreseeable future will become saturated. A steady state appears to exist for statistics. Present trends in Canada will probably lead to an increase in the opportunities for statisticians with the government. Some applied mathematicians, such as those in modern applied mathematics, will find employment, particularly with the government. Pure mathematicians are likely to be the least in demand, but even they may be valuably employed if they will broaden their knowledge through reeducation, either formally or by self study.

We have examined the employment patterns for each area for the past five year period (1970-75) through the statistics provided by the universities to ACAP. These data are too incomplete to justify including in this report. However, it is clear that employment opportunities still occur, sometimes outside of Ontario and even Canada. Of course, many jobs in Ontario are filled by candidates from other provinces and other countries.

Many of the present mathematics faculty in Ontario universities have come from outside Canada. On balance, it appears that Ontario has supplied more of the trained mathematicians for the rest of Canada than it has received in return. This may be less true in the future.

It is pertinent to consider the numbers of mathematicians educated in the United States. In 1972-73, 1,340 PhDs were graduated for all areas combined (source: National Center for Education Statistics). The number of PhDs projected for 1979 is 1200. Even in this most highly developed society, many of these graduates will not find suitable positions (G. S. Young, CBMS Newsletter). An upper limit to the number that will find suitable jobs is probably about 1000 PhDs. However, such projections are subject to large uncertainties. For 1985, the National Science Foundation and the US Bureau of Labor, both organizations with substantial resources for such studies, disagree signigicantly in their predictions of the supply and demand for PhDs. A summary of the findings of these two agencies is given in Table VI. Nevertheless, it is important to stress that both predict that there will be a substantial surplus of PhDs in mathematics in 1985.

Scaling down on the basis of population only, the 1000 figure for 1979 becomes 38 PhDs per year for Ontario and 107 PhDs per year for Canada as a whole. When due consideration is given to our earlier comments, we feel that a production rate of 50 PhDs per year for Ontario would lead to unemployment problems; a figure of 40 PhDs per year would be more realistic for 1975-80.

How should the 40 PhDs be distributed over the different areas? Probably about 10 per area is a defensible choice. Although there may not be 10 openings per year for pure mathematicians, this area is so great in scope that in order to provide the spectra in training over the various specialties about 10 graduates per year are needed. Applied mathematics is a rather nebulous term (see section II-B) and covers a wide range of subjects. Here, however, training will also be provided by other departments, for example in relativity and quantum theory by physics and chemistry departments, and in control theory, solid and fluid mechanics by engineering departments. Ten PhDs per year from mathematics departments would probably represent an upper limit. In statistics, 10 PhDs would probably satisfy the present demand; this figure might rise by 1980. In computer science, probably more than 10 graduates could find employment now; however, many of these jobs could also be filled with master's graduates. Further, by 1980 the demand for PhDs in this area may have stabilized to 10 or less.

We now consider the numbers of master's graduates per year. Some of these graduates will fill jobs that make less use of their training. Examples might be in accountancy aspects of business, and in assisting economists who lack mathematical training with modelling and statistical analysis. We feel that if the baccalaureate in mathematics can be accepted as worthwhile by the taxpayer, then an extra year to obtain

TABLE VI

COMPARISONS BY THE NATIONAL SCIENCE FOUNDATION AND THE BUREAU OF LABOR STATISTICS OF EMPLOYMENT PROSPECTS FOR PhDs IN THE US FOR 1985

	Number of PhDs							
Field	National Science Foundation				Bureau of Labor Statistics			
	Supply	Demand	Surplus	Percent Surplus	Supply	Demand	Surplus	Percent Surplus
Physical sciences	85,200	76,000	9,200	10.8	118,700	91,700	27,000	22.7
Engineering	63,300	45,000	18,300	28.9	80,100	59,100	21,000	26.2
Mathematics	21,600	16,000	5,600	25.9	31,400	19,800	11,600	36.9
Life sciences	92,100	85,000	7,100	7.7	137,700	73,100	64,600	46.9
Social sciences	112,700	71,000	41,700	37.0	153,700	87,100	66,600	43.3

Source: Science, 191, 363 (1976).

the master's degree will not rock any boats. We therefore believe that no limitations should be placed on the number of master's candidates other than the supply and interest of suitably qualified students. However, we refer the reader to section I-7 for important provisos.

How is the recent rate of production of PhDs, about 70 per year, to be reconciled with our recommended figure of about 40 per year? There are signs from the enrolment numbers that a decline is developing. Changes in Canada's immigration policies, together with restrictions in the awarding of NRC grants will ensure that the number of students from outside Canada will decrease. Publicity on the lack of jobs, must have reached the students' ears by now, and will undoubtedly show up in decreased enrolment by Canadians. These factors, coupled with high admission requirements, will probably bring the numbers into line. We therefore do not see the need to arbitrarily close down some graduate programmes. Nevertheless we do believe that there are too many programmes offered in Ontario at the present, and that some of the marginally viable ones will not survive in the new climate.

Recommendation 1

We recommend that:

i) the enrolment statistics be regularly monitored by the discipline group in the mathematical sciences, and if excessive fluctuations, either up or down, occur that remedial action be initiated;

ii) the number of PhDs in mathematical sciences awarded by the Ontario universities total about 40 per year, with about 10 from each of the four areas;

iii) that the figures given in ii) be reconsidered for possible modification at regular intervals in the future.

7. Other remarks

At virtually every university we visited, we were told of financial constraints, real or about to become so, and projections for the future concerning government grants that were at least discouraging. We heard that overcrowding could not be relieved, that new fields could not be begun, and that weak fields could not be shored up with new appointments. Although money may not have been the sole cause, we learned of some faculty discontent and mistrust, both with the central administration, and within departments.

If these financial constraints develop further, there may be a tendency to retreat into an Ontario isolation. We would deplore any attempt to set up a closed Ontario system. In the long run, we believe this course of action would be a disaster for Ontario. As we stated earlier, the mathematical sciences in Ontario have not reached a first-rank position in the world, although there are several very able and a few outstanding individuals. To aid further development, it is essential that contact outside Ontario be maintained, and perhaps even strengthened.

We were impressed by the special seminar days, summer schools and the visiting professor programmes that some departments have and by the Canadian Mathematical Congress. We encourage the retention of sabbatical and other leaves to world centres. We urge that priority be given for the funding of travel to conferences and for consultations. These activities would help to compensate for the lack of new positions and new buildings.

By the same token, we believe that the admission of some students from outside Ontario and from outside Canada will provide a form of contact with the outside world that will also add to the development of mathematics in Ontario. However, the numbers of foreign students should be relatively small, say up to 20 or 25% of the total. To achieve the goal we have in mind, these students should come from a variety of countries, and should have some reasonable preparation and promise for research in mathematics. We have observed that some departments have the majority of their students from one part of the world, usually Asia. Some of these students are in their middle or late twenties on admittance. We believe that programmes based on this sort of enrolment are not viable, and we hope that a tightening of immigration and entrance requirements with due attention to age will ensure that either these programmes die, or else become populated with a different mix of students.

The universities in Ontario were set up as autonomous entities before the creation of the Council of Ontario Universities. The reasons are not easily discernable to us; there are, however, obvious advantages to this arrangement. First of all, the needs of specific regions of the province can be met easily, and the benefits offered by the siting of a university are decentralized. Secondly, competition is possible that may lead to the attainment of high standards as well as a large student body. Thirdly, the sense of being master of one's fate is attractive to faculty, students, and administration alike. Indeed, in the absence of any financial limit, it may be convincingly argued that the creation of several independent institutions is by far the best route to follow.

The pattern in Ontario has largely been duplicated in the rest of the Canadian provinces. Some institutions that were nurtured for a time by older, well established universities have ultimately achieved independence; examples are to be found in Alberta, Saskatchewan, and Manitoba. Only in Quebec is there a multicampus Université du Quebec, and even this system competes with several other provincially supported universities, both franco- and anglophone. The situation is quite different in many highly populated states in the US. There, one state university often has many campuses; examples are California, New York, and Minnesota. There still exist several important independent universities, typically with private funding. Some are tending to be absorbed into state systems; examples are Syracuse and Buffalo. The state system has some kind of central authority, perhaps a common board. Although such systems may lead to a lack of competition, some arbitrariness, and even some sterility, they can in principle at least, rationalize the offerings and arrange for the total needs of overall objectives.

In the present climate, it seems that cooperation between universities in Ontario must be fostered. Some specific suggestions on ways to achieve meaningful collaboration in the mathematical sciences are made in section III-2.

CHAPTER II

AREA REPORTS

1. General introduction

In preparing the four area reports presented in this chapter, we have relied heavily on the confidential reports submitted by the ACAP advisors to the individual universities whose graduate programmes were reviewed. Both we and the advisors also examined the factual information supplied to us by ACAP before and during our visits to individual universities. However, the volume of the data presented to us was far too great for extensive analysis. Moreover, we found it hard to interpret the fractional assignments and multiple assignments of individuals to areas and subareas, even after visiting universities.

Therefore we have had to rely on our own impressions to a considerable extent, gained in the course of reading and taking notes on published research, on discussions with faculty and graduate students, and on an already existing familiarity with the research and scientific reputation of the faculty concerned.

In our introductions to the four area reports, we have also relied on the preambles of the advisors, but have freely expressed our own views, as well as modifying and reorganizing the preambles of the advisors when we felt this contributed significantly to clarity or to consistency between the different areas.

We have also tried to correlate the area reports with the ideas and recommendations presented in Chapter I, at the risk of some repetition. Finally, we have considered with especial care the responses of the universities to the advisors' reports.

2. Grouping of universities

The bulk of this chapter will consist of our assessments of the graduate programmes of individual universities in the four ACAP-specified areas. Within each area, we arranged our reports on individual universities into four sets, set A being the two universities with large departments, set B being the older universities of eastern Ontario, set C the older universities of western Ontario and set D formed of three newer universities:

A) Toronto, Waterloo
B) Carleton, Ottawa, Queen's
C) McMaster, Western, Windsor
D) Guelph, Lakehead, York

3. Some basic observations

Before making our four individual area reports, we also wish to restate briefly at the risk of repetition some general observations that seem to us to apply to most of these areas.

1. Over the past 25 years, there has been a very large increase in the number of Ontario faculty members active in mathematical research.

2. This is beneficial in many ways, in particular because it has made study abroad a far less necessary part of the preparation for a successful academic career (but see paragraph #12).

3. Indeed, Ontario universities now have a capacity for training many more graduate students than are likely to find jobs in Canada for which this training is suitable.

4. Hence we urge that the emphasis of graduate instruction and research be on increasing quality and relevance; the quantity should remain constant or be allowed to decrease.

5. Specifically, barring unforeseeable future developments, we question the wisdom of producing more than about 10 new PhDs annually in each of the four areas in question; except in computer science, in which only Toronto and Waterloo have PhD programmes, this means that some existing PhD programmes will not even produce one PhD per year.

6. Actually, this seems consistent with current enrolment trends for Canadian graduate students, but it is far below the combined ambitions of all present Ontario faculty members and university administrations, some of whom aspire for continued expansion.

7. We and the advisors have studied the size and distribution of NRC grants. They appear to achieve the purpose for which they were designed, by supporting equitably much worthwhile research of quality and relevance. However, we urge that research projects be dissociated from PhD production. As has been explained in section I-4, faculty research should be dissociated from the production of PhD theses.

8. We hold the view that research should be useful or interesting in its own right, and that PhD candidates should be free to select research topics on the basis of interest and relevance, and not because money is available for research assistants. This does not mean, however, that research assistantships cannot be used as part of the screening process for PhDs, or for reducing the burden on faculty members of detailed computation and literature search.

9. Participating as a research assistant on an interesting and relevant cooperative study would enhance any career (e.g., high school teaching) for which mathematical training is required.

10. We are of the opinion that doctoral candidates should have passed the master's degree requirements with high distinction, after which they should not ordinarily be required to take additional course work followed by written examinations.

11. For the above reasons, we believe that the viability of a graduate lecture course programme should not depend on the number of doctoral candidates at any particular university. We think it inappropriate to recruit doctoral candidates merely to justify the giving of advanced specialized courses. Seminars at which lectures by students take the place of written examinations seem to us usually better for doctoral candidates.

To put the preceding points less formally, we would observe that the present economic climate has led to a large cutback in the number of graduate students. Although this has been a disappointment with respect to expectations and projections of the past, the lack of a graduate student is not necessarily a serious loss to a faculty member. Mathematicians in Ontario are fortunate in that they have large numbers of creative colleagues, are in general close to colleagues of nearby institutions and belong to departments which have programmes involving distinguished visitors. They have ample opportunity to engage in satisfying and fruitful research without supervising PhD candidates.

Before getting down to individual areas and universities, we observe again that, although we have conformed to the format of a separate report in each of the four areas, we emphasize that a substantial proportion of university research and graduate training should be interdisciplinary, and does not fit neatly into any one area or even academic subject. This is true, for example, of scientific computing and of attempts to make the internal logic of physical models mathematically rigorous.

12. A final question concerns the extent to which Ontario or Canada should have a self-contained "mathematical ecosystem." We think that at least 60% of any graduate student body should have been educated in Canada, and should achieve a master's degree by age 23 or 24. Of course, there can also be people having work experience who need further advanced training (especially in statistics and computer science), but otherwise failure to attract enough such graduate students must be accepted as a sign that a given graduate programme is not needed or even desired. On the other hand, we think that provincialism is a real danger. Not only do we think it imperative that most PhDs be familiar with more than one university environment (though job experience is a partial substitute), but also that a substantial proportion of the professorial staff in Ontario universities should have some pre- or post-doctoral experience outside of Canada. Otherwise the style and content of Canadian research might gradually become too inbred.

A. PURE MATHEMATICS

Introduction

We take it for granted that before being admitted, graduate students in pure mathematics will ordinarily have completed the equivalent of a Canadian honours undergraduate concentration in some area of the mathematical sciences. We see no reason for differentiating strongly between these areas at the undergraduate level; indeed, we think that undergraduate education should normally be regarded as pre-professional.

Such students should be able to fulfill master's degree requirements in one year. Others, having to fill gaps in their undergraduate education may need more than one year of graduate education before becoming adequately prepared either for outside employment or for embarking on research. Though we believe in maintaining uniform minimum standards, we think that a diversity of patterns is sound in education.

Besides taking two or three graduate courses in core mathematics, master's candidates in pure mathematics might well also take courses in applied mathematics, computer science, and/or statistics if not already taken as undergraduates. In addition, we think that electives such as the history of mathematics, taken for interest, or reading and research courses taken in connection with the preparation of a master's thesis, should be encouraged for master's students planning a career in secondary education.

We would hope that students with a master's degree having such backgrounds would be educated both in breadth and depth, would be able to think for themselves and would retain a keen interest in mathematics. We believe that graduate education in mathematics should be a stimulating experience and not drudgery.

Those students showing the greatest ability and interest should be seriously considered as suitable candidates for a PhD, if they so wish. Such exceptional students will normally have, after passing with high honours three graduate courses in core mathematics, a very adequate grounding in advanced mathematics. Here we have in mind the equivalent of the PhD qualifying examination in mathematics at a good university in the United States.

We think that doctoral candidates should have passed the master's degree requirements with high distinction, after which they should not ordinarily be required to take additional course work followed by written examinations. At the doctoral level, what is required is evidence of originality and a promise of continuation of research. Hence, a doctoral dissertation which represents a slavish imitation of the work of the thesis advisor done under much prodding represents no service to the student and certainly no honour to the advisor. Besides, the inclusion of such graduates simply adds a polluting factor to the current oversupply of PhDs. Because the prospects of obtaining a permanent academic position at a university are poor, it is of particular importance that the graduate education of the doctoral student should not be narrowly centred around the topic of the dissertation. A broadly educated pure mathematician should still be able to obtain reasonable employment even though such employment will not usually make full use of his training.

The comments following observation 11 in the general introduction to Chapter II and referring to the cutback in the number of graduate students, and the opportunity to engage in satisfying and fruitful research without supervising PhD students have special relevance in the area of pure mathematics.

Finally, we wish to express our general satisfaction at the high standards that have been maintained in awarding master's and doctoral degrees at Ontario universities. We are not recommending that any university now authorized to award these degrees be disqualified from so doing in the future. We simply believe that the inexorable laws of supply and demand make the achievement of even higher standards (yet not more onerous for gifted students) mandatory for the future.

University of Toronto

The department of pure mathematics of the University of Toronto has a large staff with many members of international reputation in various areas, particularly in analysis and in geometry. There is considerable strength in a broad spectrum of mathematics such as topology, logic, number theory, algebra and differential equations. The overall strength in algebra and number theory appears to be below that of analysis.

The University of Toronto has the oldest and most distinguished tradition in Canada in the training of mathematicians at the undergraduate as well as graduate level. Their honours programme in mathematics ranked among the best on the North American continent. This is reflected in the outstanding past performance of Toronto undergraduate mathematics honours students in the Putnam competition. Moreover, the graduate students interviewed by our advisors impressed them as definitely the best group they met in Ontario. Furthermore, their research seemed to be concerned with important problems in the mainstream of mathematics. Because of this, we think that the Toronto faculty in pure mathematics could give training of high quality to more Canadian graduate students, and produce as many as 5 PhDs per year.

An effort should be made to centralize and improve the mathematics housing by constructing a new building perhaps similar to those at Queen's and Waterloo, where all the mathematical sciences are under one roof. Well planned physical plant greatly facilitates communication!

Finally, we think that Toronto could make greater use of its faculty resources if it reviewed objectively: (a) the connections between the various fields of pure mathematics, with an eye to maintaining a healthy balance between these fields, (b) the extent to which specialization is desirable at the master's and doctoral levels, (c) the balance between undergraduate and graduate teaching effort, and (d) the extent to which the four areas of pure mathematics, applied mathematics, statistics, and computer science should interact. Such a review, though time-consuming, could help to maintain Toronto's traditional excellence and would be helpful to all the Ontario universities.

Recommendation 2

We recommend that:

i) the space available for the mathematical sciences be increased and centralized;

ii) the MSc and PhD programmes of the department should be continued;

iii) about 5 PhDs in pure mathematics per year should be produced;

iv) the whole programme of graduate work in pure mathematics should be reconsidered within the department.

University of Waterloo

The University of Waterloo has a large staff in pure mathematics distributed over many fields. Its greatest strength is concentrated in the Department of Combinatorics and Optimization, some of whose members have an established international reputation. This component of the staff is one of the strongest of its kind in the world. In the other fields of pure mathematics, we find considerable strength in those parts of functional analysis concerned with functional equations occurring in real and complex analysis, and in those which relate to applied mathematics through probability and information theory. Work in these areas is further promoted by a continuous stream of visitors and the publication of an international journal devoted almost entirely to the theory of functional equations. In addition the staff contains a very active group working in algebra with particular emphasis on category theory, logic and universal algebra.

The department has attracted a substantial number of graduate students who tend to work mainly in the areas described above. We found most of the theses produced to be of reasonable quality. However, some doctoral theses were almost exclusively computational in nature with little significant theoretical content. While fully recognizing the importance and difficulty of combinatorics (as in classical number theory), we feel that every doctoral thesis in pure mathematics should be organized around clearly stated theoretical questions. We recognize the importance of high level computation for research in combinatorics. However, we think that this kind of research assistance can often be provided by students writing master's theses.

In view of the size and quality of the pure mathematics staff at Waterloo, our general recommendation concerning the market for PhDs

(10 per year in pure mathematics for all Ontario universities together) may bear especially heavily on Waterloo. Nevertheless, we think that it should be taken very seriously. We especially urge that decisive steps be taken to avoid premature overspecialization, perhaps by course requirements or a uniform qualifying examination in pure mathematics which must be passed before students are accepted as doctoral candidates.

Recommendation 3

We recommend that:

i) there should be a uniform qualifying examination for intending doctoral candidates in pure mathematics including those in the Department of Combinatorics and Optimization;

ii) the MMath, MPhil and PhD programmes continue to strengthen their minimum standards;

iii) about three PhDs per year should be produced in the pure mathematics area at Waterloo.

Carleton University

Carleton University has a large and reasonably well balanced staff of pure mathematicians. It is particularly strong in algebra and related subjects such as number theory and geometry. In addition the department has some outstanding analysts working in potential theory and classical analysis, which nicely rounds out the activities in the other more abstract areas mentioned.

The staff appears to be an enthusiastic and very active group; moreover it shows a great deal of initiative in supplementing its research programmes with a steady stream of distinguished visitors spread over many areas of mathematics. The algebra days organized by the department are now a firmly established activity of the department and contribute substantially to the intellectual life in the Ottawa area.

Since the start (some six years ago) of a graduate programme leading to a doctoral degree, the department has developed an honours undergraduate programme of high quality and breadth. This helps to provide an excellent base of courses for the graduate programme.

Helped by its location in Canada's capital, the department seems to be able to attract an adequate number of qualified and gifted students. The overall quality of the doctoral theses we examined was high, if not outstanding. The morale of the students we interviewed was good, and most of them were happy with their decision to go to Carleton University for their graduate work. We see no special problems in maintaining an effective programme in the near future, if the provincial government continues to support graduate work at the present level.

Recommendation 4

We recommend that:

i) the MSc programme continue;

ii) about one PhD a year should be produced in the pure mathematics area at Carleton.

University of Ottawa

The University of Ottawa offers an attractive and broad programme of courses in pure mathematics. It is bilingual, and therefore can play a special role in servicing the needs of French-speaking students. This seems to be especially valuable for new students, although all of the more advanced students we talked to could understand English without trouble.

The staff was enthusiastic about a new master of arts programme for mathematics teachers (MAT degree). We think that it should be a major part of the department's graduate programme to meet whatever need there is for well trained teachers of mathematics who will teach in French.

The theses produced in the master's programme, largely by foreign students, were of acceptable quality. Our advisors considered the doctoral theses to be substandard. The number of doctoral graduates over the last ten years has been so small that continuance of the programme is becoming questionable. This seems to be especially true because of the lack of a group of outstanding mathematicians in any one field. Since there are very few Canadian graduate students or undergraduate honours students in mathematics, we see no reason why this situation should change.

Possibly, if the francophone Canadian population produces more young people who wish to and are able to do mathematical research of good quality, the situation might improve. But we found only one such student who was entering a doctoral programme. His prospective thesis advisor is a mathematician from France visiting Ottawa for a year. The student expected to go to Paris to complete his studies. Hence, while the hope is laudable, and while no other Ontario university can perform this specific role, there is a strong onus on the part of the University of Ottawa to show that it can attract sufficiently many French-speaking students of high enough calibre. The attraction of such students is especially difficult because of the competition from well established universities in the province of Quebec, especially the Université de Montreal.

Under present circumstances we seriously question the viability of the doctoral programme in pure mathematics. While it should be allowed to continue for a further two years, the programme should then be externally appraised.

Recommendation 5

We recommend that:

i) the proposed MAT programme should be developed;
ii) the MSc and MA programmes should continue;
iii) the doctoral programme in pure mathematics should continue for two years after which its viability should be subject to external appraisal.

Queen's University

Queen's University has a large and well balanced staff in pure mathematics. Thus it has a very active group working in the areas of modern algebra, notably in commutative algebra, algebraic geometry and number theory. These activities have attracted many visitors from Canada and abroad. During the last three years, the department has conducted a summer programme which is loosely referred to as Queen's open house for algebraists. We observed that these activities have contributed substantially to the graduate programme.

There is also a wide-ranging strength in functional analysis, which extends from operator theory with applications to physics and the mathematical foundations of quantum mechanics and differential operators, to areas in pure functional analysis such as measure and integration theory, the theory of normed linear spaces and the theory of Riesz spaces.

The department has a long tradition going back to the days of Professor R. L. Jeffery in the training of mathematicians at the undergraduate as well as graduate level. The programmes are of excellent quality and breadth and should certainly continue at their present level. Indeed, it seems especially true at Queen's that the staff could capably handle a larger number of qualified graduate students.

The department is housed in a new building on the campus named after R. L. Jeffery; it is the most functional building housing a mathematics department of this size[*] that we have ever seen.

Recommendation 6

We recommend that the MA, MSc and PhD programmes should continue at their present level.

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[*] That of the University of Waterloo is much larger ---- and Toronto would also need a considerably larger building.

McMaster University

We now turn to the universities located in western Ontario, other than Waterloo.

The mathematics department at McMaster University includes a large highly expert group in algebra, especially in universal algebra, where a measure of international reputation has been achieved. There are also a few specialists of recognized quality in other areas, notably in topological vector spaces and combinatorics, but the overall research effort in these areas, while acceptable, does not have a comparable international reputation.

The number of graduate students is large (about 20 doctoral students and 10 master's students) and the department has no difficulty in accommodating this number. Partly because the undergraduate programme is broad and of high quality, these students have a good range of courses from which to choose. The number of foreign students is small, but during the last few years the department has been experiencing greater difficulty in attracting qualified Canadian students.

The majority of the doctoral theses which we examined were, understandably, in the area of algebra. Their overall quality was acceptable, although we did not see any which we could describe as really outstanding. The same remark applies to the quality of the master's theses.

The students we interviewed were on the whole content with the education they were receiving. Of course, they expressed their fears about the prospects of obtaining a position in the academic world. The department would do well to look into this matter, and to see whether they could change part of the student's training over into areas of applicable mathematics such as statistics and computer science. Likewise, the pure analysts should try to establish closer relations with the applied mathematicians. Unless some positive steps are taken, we think that it will be difficult to maintain a lively and vital programme in pure analysis at McMaster. More generally, we think that steps should be taken to broaden and deepen the training of the pure mathematicians, and that the doctoral theses should be fewer and of higher quality.

Recommendation 7

We recommend that:

i) the MSc programme should continue;

ii) steps should be taken to make the analysis section of the PhD programme more in line with current interests and applications;

iii) subject to (ii), the PhD programme should continue aiming to produce one or two PhDs per year.

University of Western Ontario

There is considerable basic strength in the mathematical sciences at the University of Western Ontario. Thus the undergraduate honours programme is of high quality, and graduates of this programme are well prepared for graduate work. As a result, little additional effort is required to maintain a good master's programme in pure mathematics.

Moreover, it is a policy of the university to have a majority of its graduate students Canadian. Hence, there is not the domination of the graduate class by foreign students which we have at some Ontario universities, although foreign students form a large part of the graduate student body.

However, we foresee a number of difficulties in maintaining a good doctoral programme. First, it should be recognized that the main research strength of the department is in classical analysis and this largely in one narrow area, namely, summability theory. There is also some strength in algebra. As a result of this limited coverage the doctoral theses tend to be unimaginative and technical. In fact, most of the theses were in some aspect of summability or in semi-group or automata theory, and all of the students we interviewed were working in these topics.

Stated another way, there are only a few senior faculty members who have strong research reputations, and these are concentrated in two or three very limited fields. Unless the research capability of the faculty can be substantially broadened, we question its ability to attract enough qualified graduate students in the future to maintain a viable doctoral programme. The bulk of the faculty is young, about one third of these being non-tenured. To broaden the doctoral programme, it would be necessary to appoint several more strong research mathematicians, which appointments would probably lead to a reduction in the number of non-tenured staff.

It would also be helpful to foster cooperation between pure and applied mathematicians, which has been poor in the past. We were told that attempts are now being made to resolve the underlying disputes in a satisfactory way. If this can be done, applied mathematicians whose interests include theory could help considerably in bolstering the doctoral programme in pure mathematics.

Recommendation 8

We recommend that:

i) the MA programme should continue;

ii) efforts should be made to broaden the PhD programme. In the meantime the programme should continue for two years, after which its viability should be reappraised externally.

University of Windsor

The faculty of mathematics at the University of Windsor is so small that to compartmentalize its activities into four areas hardly makes sense. It has lost through retirement its only distinguished senior pure mathematician. Although this member was not active in supervising doctoral theses, he was largely responsible for upgrading the undergraduate honours programme, which we find often includes a good nucleus of courses suitable for a master's programme.

Otherwise, the faculty of pure mathematics consists of a small number of young mathematicians, all of whom have tenure. Hence a vacancy for a senior man seems unlikely in the near future. Although one member of the faculty who now provides leadership in applied mathematics would also be capable of supervising a thesis in pure mathematics, we doubt whether this is an adequate basis for an official doctoral programme. Indeed, in its whole history, Windsor has had only three doctorates in pure mathematics, and only one thesis supervised by a present faculty member.

Moreover we wonder how many Canadian graduate students will elect, or be well advised, to pursue a doctoral programme in pure mathematics at the University of Windsor. For the above reasons, we wonder whether a continuing doctoral programme in pure mathematics will be viable there.

Recommendation 9

> We recommend that the PhD programme in pure mathematics be reappraised for its viability after two years, along with those of the University of Ottawa and the University of Western Ontario.

University of Guelph

The University of Guelph has a programme for an MSc in pure mathematics and a qualified staff, but no students. In view of this lack of students, the faculty members were interviewed regarding their attitude towards graduate work. There appeared to be no strong consensus. Two or three members were enthusiastic, some would be happy to participate, and some were indifferent. Some of the indifference centred around the valid contention that an adequate programme of courses cannot be offered without a reasonably large body of students.

However, some graduate students in statistics (section II-C) expressed a desire for a broader programme in the mathematical sciences.

In view of this, we wonder whether it might not be best for Guelph to offer a single set of courses in mathematics at the master's level, emphasizing statistics. If some graduate student taking this programme happened to qualify for an MSc in pure mathematics, his degree could bear this title.

Guelph has no current plans for a doctoral programme, and this is as it should be. Therefore no special recommendations seem called for.

Lakehead University

Because of its geographical remoteness, Lakehead University has very special problems, for example achieving contact with mathematical colleagues and with distinguished visitors available to the universities of the populous part of Ontario. Because of the small size of its staff and programmes we wonder how desirable it is to compartmentalize graduate mathematical instruction at Lakehead into four separate areas, a concern already expressed for Windsor, York and Guelph.

As things stand, Lakehead has a group of seven pure mathematicians. There is some strength in the areas of point-set topology, measure and integration theory and geometric Banach space theory. The research effort in these areas is reinforced by the work of staff members in the applied mathematics group in the theory of differential equations and numerical analysis.

Since the start of Lakehead University, the mathematicians have developed an honours undergraduate programme. This programme is now firmly established and appears to be well balanced in breadth and depth. It forms a good base for the restricted master's programme in which the whole department is actively engaged. The staff unanimously stated that the graduate programme was of great importance to them.

However, the programme seems to be unable to attract sufficiently many Canadian students. For instance, the six incoming students this year are foreign with one exception. In another direction the programme seems to have little appeal to the high school mathematics teachers in the area. In fact, the teachers who would like to get a master's degree prefer the easier correspondence programmes offered by other universities in Ontario, such as the University of Waterloo, and which as a rule do not require the student to write a thesis.

Despite these obstacles, the staff has successfully educated a small number of graduate students. The master's theses we examined were on the whole well written and in areas of mathematics of current interest. In fact, the quality of some compared favorably with those produced at other universities in Ontario.

The master's programme in pure mathematics at Lakehead is currently restricted to the areas of logic and foundations, topology and geometry, real and complex analysis, and functional analysis. Since the staff has grown to the point that they are capable of offering a reasonably broad education in pure mathematics these restrictions become artificial.

In order to make the present programme more flexible and competitive, as regards attracting Canadian students, we recommend that serious consideration should be given to authorizing the department to offer an unrestricted programme at the master's level in mathematics, and to allow the department to award the master's degrees by course work, or by thesis as warranted. Some emphasis on numerical analysis would be appropriate. The department could submit a new proposal along these lines for appraisal.

Recommendation 10

> We recommend that Lakehead University should be encouraged to submit for appraisal a programme for a master's in mathematics unrestricted in scope and covering a degree by course work or thesis.

York University

York University has only an MA programme in mathematics. Moreover the staffing of the courses for this programme is uneconomical because its courses have a small enrolment due to the small number of undergraduates majoring in mathematics. Part of the reason for the latter is that mathematics is in the Faculty of Arts and is housed in an arts building. The science buildings are physically removed by a considerable distance and hence the tendency is for the various science departments to offer their own mathematics courses. Perhaps the shifting of the department to facilities physically closer to the science faculty would enable the department to play a role commensurate with its resources.

Actually, its resources are considerable. In the area of combinatorial group theory it is the strongest department in Ontario. It also has strength in classical analysis and also considerable support strength in other areas. At present this talent is not used to the utmost.

The department should certainly be allowed to maintain its MA programme, and ways and means should be explored for the department to make better use of the talent available. If possible, the department should try to arrange with Toronto and other nearby universities for some of its members to participate actively, and with recognition, in their doctoral programmes. Several of the faculty at Toronto and Waterloo liked this idea, and many of the faculty at York expressed a strong desire to act as thesis advisors if such an arrangement could be made.

Recommendation 11

We recommend that:

i) the MA programme should continue;

ii) special efforts should be made to involve York faculty in the supervision of research students at other universities, especially the University of Toronto;

iii) the location of the Department of Mathematics vis-a-vis the Faculty of Arts and other faculties and colleges should be reviewed by the University.

B. APPLIED MATHEMATICS

Introduction

Four important interrelated considerations underlie our discussion of the area of applied mathematics. The first is the difficulty of defining with any precision what constitutes applied mathematics. The second is that, under any reasonable definition, much work that is properly regarded as applied mathematics takes place not in mathematics departments but in other departments, notably of physics and engineering. Thirdly, there is overlap, and indeed there should be much more overlap, with the other ACAP areas. Fourthly, although the great historical triumphs of applied mathematics have been in the physical sciences, and these types of application will surely remain of great importance, there has been, in recent years, a large expansion in the range of applications of mathematical ideas and this poses a great challenge to applied mathematicians. We begin by discussing these points in a little more detail.

Essentially mathematics becomes applied when it is used to solve problems in the real world "neither seeking nor avoiding mathematical difficulties" (Rayleigh). Because the same mathematical technique may be applicable in many different fields, a good training in applied mathematics should be aimed at producing a versatile scientist. Yet all branches of mathematics are potentially applicable, and indeed once one application is found for a particular kind of mathematical idea analogy will often suggest others. Thus the mathematics first introduced to describe in highly idealized form competition between species (predator - prey models) later turned out to be central for nuclear reactor theory, where it has become very precise and sophisticated, and has applications too in operations research. Thus, potentially, applied mathematics covers an enormous area, being coextensive in one sense with quantitative thinking. In this broad sense, the area lacks unity and is much too large to be covered completely in any one institution.

Further, many applied mathematicians study technique as such in at least some of their work, and in this respect might be considered pure mathematicians. To draw any rigid division between ACAP areas is wrong. One of the dangers of the subject, however, is the specialization of arid exercises in technique, divorced from real applications and yet of no lasting significance as pure mathematics, and we regard genuine involvement in applications as crucial for the health of any applied mathematics group.

Applied mathematical work, including the supervision of research students, that is very directly concerned with particular applications is often found in the department of application. While in our visits to universities we heard much of such work, we were not able to assess it in any systematic fashion; see section III-6. This means, in particular, that our recommendations for individual universities inevitably cannot be as detailed as for the other areas.

Until fairly recently, the great majority of applications of mathematics have concerned the physical sciences, either in classical continuum physics, relativity and quantum theory, or in applications to aeronautics, chemical engineering, etc. There are, however, new challenging problems requiring applied mathematical work arising in many other fields, for instance in earth and planetary physics (including meterology, oceanography, etc.), ecology, genetics, virology, biochemistry, neurophysiology, theoretical psychology, control theory, systems analysis, operations research, management science, business and economics modelling.

There are several implications of this broadening. First some kinds of application remain active and exciting for fairly short periods, 10 years or so. Because a faculty member may be active in his subject for 30-40 years, it follows that an appreciable proportion of applied mathematics faculty must be prepared to change their main fields of interest, possibly several times. Continuous reappraisal of topics of interest is required. The area will not remain vital if departments of applied mathematics consist largely of self-perpetuating groups.

Secondly, while we appreciate the importance of the traditional fields of work in applied mathematics, the employment prospects there are severely limited and we strongly believe that the training of applied mathematicians should be more deliberately aimed at the main employment opportunities. The recent distressing decline in the number of applications for graduate work in applied mathematics is probably connected with students' appreciation of the limited job prospects.

Connected with this, and for other reasons as well, some changes in subject emphasis seem called for. The traditional topics such as ordinary and partial differential equations, asymptotic expansion, etc., remain important of course. In addition, however, links with computer science and some of the newer topics in pure mathematics need fostering; further, some knowledge of applied probability and to some extent statistics will often be required by the applied mathematician. Indeed, the fairly widespread separation of statistics and computer science from mathematics has weakened applied mathematics internationally. Mathematics departments are themselves largely responsible for this separation by their failure to support these subjects adequately when they first became vigorous.

Although our information about programmes in other departments and faculties is incomplete, we believe that applied mathematics programmes which emphasize applications demonstrably beneficial to society will flourish most in the next decade or two. For one thing, students taking them will have better employment prospects. Such programmes might well be given in cooperation with engineering departments, just as some current programmes emphasizing questions in theoretical physics would benefit from joint supervision with physics departments. Further, we question the need for more than one doctoral programme in Ontario centring around general relativity.

Finally we note that the above discussion has important implications for the teaching of mathematics to students of other departments; see also section II-C on the teaching of statistics to such students.

While in many of the universities we visited, there was clear awareness of so-called modern applied mathematics, we feel that the full implications of a broadening of the role of applied mathematics have yet to be implemented, in Ontario and elsewhere.

We conclude the general discussion by a number of broad recommendations.

Recommendation 12

We recommend that:

i) there is a general need for reexamining the role of applied mathematics;
ii) further, there will be a need for continuing reappraisal, with attention to research and training in applications with good employment prospects in Ontario and Canada;
iii) to ensure genuine contact with applications much greater use of interdepartmental appointments is desirable.

The Coleman report is also relevant to our general remarks (see section I-1).

We now give our comments on individual universities.

University of Toronto

The University of Toronto has 29 equivalent full-time faculty members in applied mathematics. There has been considerable doctoral thesis supervision in this area, some in cooperation with computer science. Thus in 1970-75, there were 16 degrees awarded: 8 in applied analysis, 2 in classical applied mathematics, 5 in mathematical physics, and 1 in modern applied mathematics. However, there has been a dramatic recent decrease in the number of graduate students, and the staff's instructional efforts are now mainly devoted to undergraduates.

We surmise that this decrease was due to the academically oriented emphasis of the programme, and we note with approval recent concern with the modelling of tidal energy. This development seems consistent with Toronto's response to our advisors' report: that it was because "the main 'applied mathematics' approach" at the undergraduate level was supervised by the Engineering Faculty, and because "Mathematically able students who do not wish to follow the abstractions of pure mathematics have turned in increasing numbers at the undergraduate level to the new challenges of computer science, or ... such disciplines as economics". Moreover, the response continued "Until recently, applied mathematics doctoral students were required to satisfy precisely the same comprehensives as all pure mathematics students, and although a measure of flexibility has now been introduced, the pure mathematics demands on applied mathematics students are still considerable. This is a deliberate policy of the department, and has definitely acted as a control on the number of students in applied mathematics that could be considered for admission to the Department; it also implies that the students who do come concentrate more naturally in areas such as mathematical physics. Those with a real interest in interdisciplinary studies involving mathematics have tended to go to the other department, from which they availed themselves of both undergraduate and graduate courses offered by the Mathematics Department".*

If Toronto wishes to foster a strong graduate programme in applied mathematics as such, we suggest that it form an interdisciplinary committee composed of distinguished faculty members sympathetic to this idea, whose mission would be to reassess the programme and to define its focus more clearly. Such a committee should include a statistician and a computer scientist, because applied mathematics involves these two areas. We urge that the Department of Mathematics give this committee a free rein and moral support.

Recommendation 13

> We recommend that an internal interdisciplinary committee, sympathetic to applied mathematics, reconsider Toronto's role in this area. Such a committee might well recommend the formation of an independent department.

University of Waterloo

The status of applied mathematics at Waterloo has some features in common with that at Toronto. Both offer master's and doctoral programmes in all four ACAP-defined fields: (i) classical applied mathematics, (ii) mathematical physics, (iii) modern applied mathematics, and (iv) applied analysis. There are 26 full-time students. Most activity in continuum mechanics is within the Faculty of Engineering.

Also as at Toronto, there is an emphasis on applications to theoretical physics; indeed there is an especially large and active group in relativity theory. There has been a similar recent decline in graduate enrolment.

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*Quotations taken from a letter from Dean A. E. Safarian, School of Graduate Studies, University of Toronto to Dr. H. H. Yates, Executive Vice-Chairman, OCGS, dated December 16, 1975.

Another special feature is the inclusion, at Waterloo, of a distinguished and well integrated interdisciplinary effort in quantum chemistry. Here strong use is made also of computers, in cooperation with the Department of Computer Science, and the effort seems to be affiliated with the Guelph/Waterloo Centre for Graduate Work in Chemistry.

Thus, at Waterloo as at Toronto, the graduate programmes centre around applications to areas of pure science in which there are few non-academic job opportunities. A difference is that, whereas the emphasis at Toronto is on maintaining strict admission requirements, at Waterloo there seems to be a definite intention to relax such requirements in an effort to double the enrolment.

We would feel more comfortable about this proposed expansion in graduate enrolment if we had a clearer projection of job opportunities in industry, government, and academe for the master's and doctoral candidates to be trained.

There is another difference; at Waterloo, applied mathematics is very largely independent of pure mathematics.

Recommendation 14

> We recommend, with the preceding considerations in mind, a continuation of the MMath and PhD programmes at Waterloo, but with increased emphasis on areas in which there exist non-academic job opportunities. We also recommend that, in the near future, new appointments be made of faculty whose research is concerned with such areas.

Carleton University

Whereas the activity of applied mathematicians at Toronto, Waterloo, and Queen's has been concentrated around problems of theoretical physics (especially general relativity and quantum theory), and hence belongs to pure rather than applied science, the activity at Carleton centres around problems of information and systems engineering. Hence it is more "applied" in the strict sense of being of direct value to workers in industry and government in the Ottawa area. Though it is not yet as distinguished scientifically as the efforts at Toronto, Waterloo or Queen's, we think its further development should be encouraged, with additional staff appointments if possible.

Recommendation 15

We recommend that:

i) Carleton University continue to develop its interdepartmental MSc programme in Information and Systems Science and examine the possibility of a cooperative programme in this field with the University of Ottawa;

ii) the areas in which the PhD in applied mathematics is offered be more precisely defined.

University of Ottawa

The University of Ottawa offers master's programmes in all four ACAP fields, and offers a doctoral programme in mathematical physics and applied analysis. These programmes have not been successful in attracting many Canadian students in the past, and we doubt if they will in the immediate future. Hence no great loss would be sustained if the University of Ottawa had no doctoral programme in applied mathematics as such.

We consider the contemplated development of a new programme in mathematical physics, in competition with the established programmes at Toronto, Waterloo, and Queen's, to be especially ill-advised. On the other hand, with the vast number of federal government employees who might profit from graduate study, the University of Ottawa has a natural advantage over most other Ontario universities for the development of a good graduate programme in mathematical economics. In addition to supplying students, the government might well provide interesting problems for thesis projects. Indeed, it is possible to envisage many government employees being part-time students, and successfully completing combinations of work-study programmes.

In our interviews, the departments of mathematics and economics both showed an interest in developing such a programme. We and the advisors believe that this University should be encouraged to do this, even though we are aware that another ACAP group has recommended against such a development.

The University of Ottawa is developing an interdepartmental programme in general systems and information sciences, a programme that thus far has attracted three students. It would seem advisable to have some amicable coordination between this programme and the similar programme at nearby Carleton, avoiding undesirable duplication and maintaining common standards to prevent Gresham's Rule from degrading both programmes. If this can be achieved, the obvious enthusiasm that the Ottawa staff and students have for the programme would cause our advisors to endorse it for appraisal.

Recommendation 16

We recommend that the University of Ottawa be encouraged:

i) to develop an interdepartmental MSc programme in mathematical economics;

ii) to examine the possibility of a cooperative programme in the field of information and systems science with Carleton University.

Queen's University

There are 12 faculty members actively engaged in research in applied mathematics, and as many graduate students. The cooperative programme in control theory with electrical engineering seems to be the strongest and most closely knit effort. It is the only programme of its kind in Ontario. Control theory is an important branch of modern applied mathematics having direct applications to technology and significant implications for pure mathematics.

There is also a wide-ranging graduate programme in quantum theory. Both programmes seem to be on a high level of quality, but have few graduate students. Thus, they conform to a pattern which we think is quite reasonable for the future, for programmes not correlated with job opportunities.

We suggest the possibility of broadening the programme in control theory, even if only at the master's level, so as to prepare students for non-academic jobs. We would also suggest closer coordination at the graduate level with computer science, having in mind the fact that training in applied programming may be very helpful for men knowledgeable in (mathematical) physics who are seeking non-academic jobs.

Likewise, we suggest that the promising interdisciplinary efforts with biology (including STATLAB) be given greater visibility by being cross-referenced as part of the applied mathematics effort.

Recommendation 17

We recommend continuation of the existing MA, MSc and PhD programmes in applied mathematics at Queen's University, but with increased emphasis at the master's level on applications associated with non-academic employment opportunities.

University of Western Ontario

The MSc and PhD programmes in applied mathematics at UWO are supervised by sixteen faculty members. These faculty members have on the whole remained active in research over the years since they joined the faculty, and have produced a steady stream of research publications, some of high quality. Several enjoy international reputations which reflect credit on their university and the province of Ontario. The graduate courses make up a strong MSc programme in applied mathematics; we noticed no significant gaps. Both the quantity and quality of the research output are good, particularly in continuum mechanics, related applied analysis, and theoretical physics (e.g. positron annihilation and plasma theory).

We feel that the staff should continue its strong MSc programme in applied mathematics, with an occasional PhD. But it is unlikely to realise its full potential until certain deep-rooted problems within the University of Western Ontario are resolved. In particular, the future organization of mathematical physics and theoretical physics within the University is under review as a consequence of the recent ACAP physics assessment. Certain tensions seem also to have been generated between the Departments of Pure and Applied Mathematics. The University administration is aware of these problems and has formed two internal committees to study relevant aspects of them. We hope that these committees will make positive recommendations for applied mathematics at UWO, and will take into account the general observations made earlier in this report.

Recommendation 18

> We recommend that the University of Western Ontario continues its strong programme in applied mathematics, turning out an occasional PhD. Any other recommendations must be deferred until after existing committees have succeeded in resolving internal problems.

University of Windsor

There are eight faculty members engaged in applied mathematics, almost all in the mechanics of solids and fluids or in applied analysis. The group working on the mechanics of solids is unique in Ontario; although mostly concerned with "ideal" solids, it appears to cooperate well with the Departments of Civil and Mechanical Engineering. There are about 10 graduate students, and the doctoral theses have been good, in the mainstream of current research and read by distinguished external experts.

Recommendation 19

> We recommend a continuation of these programmes, but with an internal review in the near future of non-academic employment opportunities for graduates of the doctoral programme.

University of Guelph

The Department of Mathematics and Statistics has so far attracted only one (part-time) graduate student in applied mathematics, though the staff could easily mount an MSc programme. We suggest that a programme emphasizing applications of mathematics and statistics to agriculture and biology might well attract students and be unique in Ontario. In most areas, it would be difficult to compete with nearby Waterloo.

No specific recommendation seems called for.

Other programmes

No other graduate programmes in applied mathematics as such were called to our attention, although several existing degree programmes discussed in other sections could be construed as having an applied component.

C. STATISTICS

Introduction

This section of our report deals primarily with comments on individual universities' work in statistics.

In our opinion, a healthy faculty group in statistics must be involved in research and have good contact with applications. That is necessary for lively undergraduate teaching if for no other reason. Whether it is necessary to have doctoral students, or even specialized graduate courses, is less clear; with intelligent use of the opportunities for interuniversity collaboration, a group could be active and successful in research without graduate students. We have discussed this important matter further in section I.

We recognize a useful nonrigid distinction between applied probability and statistics; the former deals with the study of probability models arising in the physical and biological sciences, operations research, etc., whereas the latter is primarily concerned with the analysis of data and the design of investigations. With some exceptions, we note a surprising province-wide weakness in the former.

As with other kinds of application of mathematical ideas, close correlation between theory and application is vital in statistics. Good applied statistics goes together with a concern for new theory; mathematical statistical theory that is not ultimately motivated by or related to any application is likely to be arid. For this reason we have not followed the ACAP subdivision of statistics into five or more fields (mathematical statistics, applied statistics, etc.). In any case, to have done so would have involved dealing with very small numbers of faculty in any institution.

As noted again in section III-6 of our report, the consultants and advisors on their visits were able to meet faculty from other departments but not to make a systematic assessment of statistical work outside the mathematics or statistics departments. Certainly full appreciation of the work in statistics on any campus would involve examination of work in many other departments: economics, epidemiology, physics, law, agriculture, etc.

We believe that statistics has a good future in Ontario and generally, essentially because as well as already established types of application, there remain many problems in industry, agriculture, government and the professions with an as yet unsolved or unrecognized major statistical component. For that reason we believe that the effective demand for statisticians with a graduate qualification will persist and probably increase, provided that statistical training achieves a satisfactory balance between theory and application. We found some tendency to consider a master's programme in applied statistics to be less demanding than one in mathematical statistics, and this we regard as a dangerous view. Good work in applied statistics nearly always calls for much more than mechanical application of prepackaged methods.

It is important to distinguish between the role of master's programmes as a preliminary to doctoral work and as a terminal preparation for applied work. For the latter purpose, a programme taking a well qualified student twelve months of work should normally include a thesis or major project, and the programme should be planned to lay the foundation for ultimate independent work of high standard in an applied subject.

There are a number of exceptionally able statisticians and probabilists in the province's universities. On the other hand, most of the institutions contain also faculty of uncertain quality, inactive in research and without compensating special strengths, so far as we could judge.

The numbers and qualities of the graduate student bodies in statistics varied widely and sometimes puzzlingly between institutions. We can only speculate on the reasons for these variations.

Some organizational problems

There are three world-wide problems in the organization of statistical work in a university:

a) how should the service teaching of statistics be handled;

b) what arrangements are appropriate for discussion of and joint work in the applications of statistics as they arise in the research of faculty and graduate students in other departments on the campus;

c) should statisticians be within a department of mathematics or in a separate department or in several departments.

Except in so far as graduate courses are concerned, problem (a) is outside our terms of reference. Nevertheless the subject is so important that we make some comments. Similar remarks are relevant to computer science and to the teaching of mathematics; see section II. Statistics can be taught to students in a particular field by various kinds of teachers, listed below in decreasing order of preference:

i) a statistician with a substantial experience of applications in that field;

ii) by a worker in the field with a sound knowledge of statistical technique and in close intellectual contact with statisticians;

iii) by a statistician familiar with other applications, but no special knowledge close to the field in question;

iv) by a pure theorist not involved in applications;

v) by a worker in the field with an inadequate knowledge of statistical ideas.

While much must depend on the merits of the individual teacher, we regard (i) as ideal, (ii) and (iii) as normally entirely satisfactory, (iv) as poor, and (v) as potentially disastrous.

One solution is that of joint appointments; it is of course essential that people so appointed should get fair promotion and tenure treatment. Another possibility is that of appointment to a central statistical group with specific commitment to applications in one or more fields. We recognize that from the point of view of departments or faculties having to give up scarce resources to support a central statistical group it may well be financially more immediately attractive to retain the teaching within their own department. Very often, however, we believe that maintenance of academic standards and overall efficiency will favour central appointments and we trust that deans will give this point fair consideration.

These remarks have relevance to areas other than statistics. They are relevant also to the second broad problem, that of statistical consulting. We were very glad to see that some Ontario university statistics groups have formally established subgroups to carry out collaborative research with faculty and students in other departments. Such groups should be strongly encouraged. They provide excellent training for students, motivation and stimulation for faculty and students, opportunities for campus-wide communication and integration as well as contributing to their immediate objective. We consider it extremely important that even if such help is loosely organized adequate financial support should be granted.

The final general problem is that of the siting of statistics groups within a department of mathematics (see section III-9). That siting may, but need not, lead to such difficulties as the insistence on criteria for degree work that are totally appropriate for pure mathematics but less universally applicable in more applied fields, and to similar emphasis in considering faculty recruitment and promotion and in the type of research that is highly regarded. There may also be a somewhat lukewarm attitude to collaborative work with other departments. Provided these difficulties are controlled, we see solid advantages to statistics being in a mathematics department with a substantial degree of autonomy over graduate work. If there is a group of viable size and calibre, and such difficulties cannot be resolved, a separate statistics department is normally to be preferred.

University of Toronto

We consider that major changes of organization are required if statistics at Toronto is to play a leading role in the province.

We were very favourably impressed with the graduate students whom we met. Further the group has an outstanding supervisor of research and a number of other faculty of great ability.

We consider, however, that the range of research topics for students should be broadened and that the links between work in theoretical statistics and in applications should be strengthened. We note that a surprisingly high proportion of the group have a poor record of published research (see Figure II, Chapter I).

A report has been prepared by Professor D. B. De Lury on the future in the University of applied statistics and of the Institute of Applied Statistics (the report was not available at the time of the visit by the advisors and consultants). We agree with the analysis in the report; indeed many of the points would be very widely applicable to universities throughout the world. We agree in particular with the conclusion that the Institute must either expand or cease to exist in its present form. We do, however, recommend very strongly that the future of applied statistics should be considered in the context of statistics as a whole, and that greater merging of theory and application should be achieved.

The setting up of a department of statistics is one possible way of attaining greater unity and sense of purpose in the statistical work at Toronto; the formal organization is less important than the clarification of objectives.

The status of probability is sometimes advanced as an argument against the institution of a separate department of statistics. This is unconvincing. Although strength in probability is required in both pure mathematics and statistical groups, there are many examples of successful collaborative arrangements involving probabilists either in statistics or in mathematics departments.

Comprehensive PhD requirements need review. Also there should be a regular statistics seminar involving collaboration with York University.

Recommendation 20

We recommend that:

i) there should be a reorganization as soon as possible of the whole of statistical work in the university;

ii) in the meantime the graduate programmes should continue;

iii) there should be a regular statistical seminar involving some collaboration with York University.

University of Waterloo

The Department of Statistics at the University of Waterloo is a large, busy and productive group with intelligent graduate students who think highly of their faculty. Its programmes show strong and imaginative initiative, and a sensible balance between theory and application. The faculty contains a number of strong, highly able people, but its quality is very uneven.

There is a large subgroup of the faculty doing research on various aspects of health and ageing. The organization of experimental work in the Faculty of Mathematics is unusual, and leads to a basic difficulty: that of maintaining high intellectual standards for a group of researchers not in intimate touch with their "home" departments of biochemistry, etc.

At the time of our visits there was some weakness in probability, pure and applied. Although this is important, if new opportunities for faculty appointments arise, additional strength in the theory of statistics should be sought.

The organization of intrauniversity consulting work in statistics should also be strengthened, and proper academic credit given for such work.

Because of the strong biological work at the University of Guelph, there should be increased collaboration with the statisticians there; a joint colloquium including in addition McMaster and Western, should be considered.

Recommendation 21

We recommend that:

i) current graduate programmes should be continued and developed in the way proposed by the university;

ii) arrangements for "consulting" work with other departments should be strengthened; there should be increased collaboration, in particular with the University of Guelph and other nearby universities.

Carleton University

In general we found high morale, among both faculty and students, an impressive programme in many ways, and intelligent, energetic planning.

On the other hand, the level of faculty scholarly quality is uneven. There is excellence in probability, in sample surveys, and in some other areas of statistics; elsewhere in statistics, we find less vigor in the concerned faculty members. We urge renewed attention to quality in future decisions about appointments.

There has been careful thought and planning about relations with the federal government. Clearly such connections have been fostered, and in ways we judge likely to be beneficial to all concerned. Specifically, the nascent cooperative programme, and the institution of sessional lectureships, seem to us excellent initiatives. A strong statistics appointment in related areas would surely be helpful to all concerned.

There should be increased collaboration with the statisticians at the University of Ottawa, both over graduate courses and for a joint seminar.

We are concerned at the apparently weak statistical and probabilistic content of the MSc programme in Information and Systems Science. The programme has been favourably appraised fairly recently and we do not recommend another external examination for the time being; internal review of this aspect is, however, called for; see also the computer science report, section II-D.

Recommendation 22

We recommend that:

i) the MSc and PhD programmes continue in accordance with the university's plan;
ii) the cooperative programme should be strongly encouraged;
iii) the role of statistics and probability in the MSc in Information and Systems Science should be given an internal review;
iv) there should be increased collaboration with the statisticians at the University of Ottawa.

University of Ottawa

The new probability and statistics group at the University of Ottawa is small and so far without graduate students. It consists of two statisticians with theoretical slants, one with an applied slant, and two probabilists; for its course structure it relies in part upon a shifting set of visitors, lecturers from outside, and help from other segments of the faculty.

It would be misleading to judge the group on the basis of a single visit. The group as a whole is not yet strong, but has promise. Leadership and direction are uncertain. We recommend that the group be re-examined in two or three years, with careful preliminary documentation.

Relationships with Carleton University are properly much on the minds of the Ottawa group. We recommend fostering and extending those relationships in probability and statistics. It is important also that the statistical group in the Department of Mathematics keep alive connections with other groups in the University, notably in biostatistics and management science.

Recommendation 23

We recommend that:

i) the programme of the group should be appraised within three years;

ii) there should be increased collaboration with statisticians at [illegible]arleton University.

Queen's University

The faculty in statistics at Queen's are of good quality; they are proceeding in a thoughtful, steady manner.

The STATLAB provides a valuable statistical service that might well be imitated by other universities. It is an integrating force for the statisticians and it provides educational opportunities for the students and research motivation for the faculty. We hope that the University will give strong support to its development.

We are surprised not to find more research in probability despite Queen's strength in neighbouring areas of mathematics.

There are not, and have not been, many doctoral students in statistics. To avoid discouraging good students with keen interests in applicable statistics, the statisticians should advertise their strengths more widely, and the department should revise its breadth requirements.

The statistics group forms a coherent, effective set with high morale and with good connections to statistical activities elsewhere on campus. There should be serious consideration of more autonomy for this group. The possibilities range from a separate department, through a semi-autonomous division of the Department of Mathematics, to such mild (yet important) moves as the shift in requirements mentioned above.

Recommendation 24

We recommend that:

i) present graduate programmes should continue;

ii) the STATLAB should be strongly encouraged;

iii) the breadth requirements for the PhD should be reviewed;

iv) the statistics group should have more autonomy.

McMaster University

Probability and statistics at McMaster are regrettably fragmented among the Departments of Mathematics, Applied Mathematics, and Clinical Epidemiology and Biostatistics, with a PhD obtainable only via the Department of Pure Mathematics. Sharp differences of view were apparent between individuals in these groups. It is essential that these differences be resolved and that a considerably more unified approach to teaching and research in statistics be adopted; students and faculty in all groups will suffer until this is achieved. We do not feel that it would be right to offer more specific suggestions on the basis of our brief visits. The difficulties are partly but not entirely explicable in terms of clashes of personality, and the choice of the appropriate individual or individuals to lead statistical work at McMaster is quite crucial.

As in many other Ontario universities, faculty quality is very heterogeneous. Only a few graduate students were available for interview when we visited in June; they did not appear strong. MSc theses were of satisfactory quality but narrow in scope.

The Department of Clinical Epidemiology and Biostatistics has been very successful in its search for funds and for space in the medical complex. A statistician of internationally broad repute has recently been appointed and brings impressive strength. Assessment of the academic strength of the work of the group as a whole is outside our terms of reference.

Recommendation 25

We recommend that:

i) there should be a reorganization of statistical work into a more unified form;
ii) there should be an external reappraisal of work in probability and statistics within three years;
iii) in the meantime the present joint MSc programme and the PhD in probability under pure mathematics should continue.

University of Western Ontario

The University of Western Ontario has had a graduate programme in statistics for many years. While it has some sources of strength, we feel that the programme lacks coherence and that the standards of thesis work need review.

Many of the graduate courses listed in the calendar appear not to be offerred in any given year; also there seems to be no substantial course in probability, a serious weakness at the doctoral level particularly.

The programme is split between two departments (Mathematics and Applied Mathematics); innovative teaching of elementary statistics seems to be primarily in the Social Science Centre. A consulting service exists, we are glad to note, but it is not yet firmly enough established to be a substantial unifying educational influence.

In the recent past, nearly all doctoral theses have been supervised by the same person. Many of them seem not to have led to publication in leading journals and we were dissatisfied with their quality judged as a whole. We are not satisfied that the best use of faculty resources has been made. There is substantial scope for increased collaboration with other universities.

Recommendation 26

We recommend that there should be an external appraisal of the whole programme to examine, in particular, the criticisms listed above.

University of Windsor

The probability and statistics group at the University of Windsor has good morale and generally sensible plans. The group needs at least two strong research-oriented additions to maintain a doctoral programme, and of these at least one should have a serious commitment to applicable statistics. With that, the group will form a small, but coherent, division within the Department of Mathematics.

There are numerous and lively professional interrelationships with faculty in other departments. Joint work with the Industrial Research Institute - now beginning - should be encouraged and developed. We note also an important demand for part-time graduate work in statistics. We talked with four graduate students, and we received a generally - although not uniformly - good impression.

A major criticism is that of apparently inadequate ties and cooperation with other universities. The Windsor faculty complained of its isolation in one corner of the province, yet Waterloo and Western Ontario are not that distant. Perhaps more to the point, Wayne State is nearby, and the University of Michigan is not far away. We recommend closer cooperation with nearby institutions in both Canada and the US. One device found useful at other Ontario universities is that of Statistics Days with invitations to all nearby statisticians. We are glad to note from the university's reply to the advisors' report that action along these lines is being taken.

Recommendation 27

We recommend that:

i) additional research-oriented appointments are essential;
ii) the MSc and PhD programmes should continue as proposed;
iii) additional contact with other universities is very important and should be developed.

University of Guelph

There is a small master's programme that should be continued, fostered and better advertised in view of the healthy atmosphere generated by the applied research carried out at the University. Master's theses are of high quality.

The excellent seminar meets often. Consideration should, however, be given to organization of a joint statistical colloquium with McMaster, Waterloo and Western.

Guelph is said to be the third largest Canadian university in total volume of overall research. Clearly there are at Guelph many research and professional opportunities for its statistics faculty and students. The faculty now do a lot of intracampus consulting for which they should receive appreciation and credit. Interested doctoral students from Waterloo might well be encouraged to work with Guelph faculty, especially on agricultural and biological problems. Biological statistics should be developed to a greater extent.

Guelph is weak in probability. Given the research in progress around the campus, the next faculty appointment should preferably be in applied probability, or biological statistics; strength in research should be an essential requirement in the person appointed.

Recommendation 28

We recommend that:

i) the master's programme continue in accordance with the university's plan;
ii) there should be emphasis on biological statistics;
iii) a new faculty appointment should put strong emphasis on research and that the fields of applied probability and biological statistics are particularly appropriate;
iv) an interuniversity seminar should be instituted.

York University

The morale at York was low at the time it was visited because of a recent increase in teaching load and the imminent departure of a valued colleague for an assistant professorship elsewhere.

The York faculty has special strength in probability; although there is some valuable work in collaboration with the Institute for Behavioural Research, there is a serious general weakness in statistics.

Only a master's degree may be awarded at present. It seems most reasonable and feasible to develop this programme further for part-time students, such as high school teachers and industrial scientists. York should seriously consider planning a specialized MSc in applied probability.

York is strong in probability, whereas the University of Toronto is not. Relations with the University of Toronto did not seem nearly as close as they could or should be. York faculty should be given an opportunity, when appropriate, to cooperate in supervising the research of doctoral students at the University of Toronto. Consideration should be given to organizing a joint probability and statistics colloquium.

Recommendation 29

We recommend that:

i) the part-time graduate programme at the master's level should be further developed;
ii) consideration should be given to a master's programme in applied probability;
iii) there should be substantially increased collaboration with University of Toronto.

D. COMPUTER SCIENCE

Introduction*

Computer science is a new discipline, and in Ontario (as elsewhere) the graduate programmes vary in their choice of fields of specialization. Toronto and Waterloo already offer both master's and doctoral degrees in all fields listed by ACAP. Most of the other universities offer, or plan to offer, graduate programmes of a more specialized kind, mainly based on the research interests of a small group of faculty members. These programmes lean towards computer applications, systems engineering, and hardware, rather than to the theoretical side of the subject.

It is not surprising that unity has seldom been achieved between vocational or applied computing on the one hand, and academic or core computer science on the other. Different universities have met the dichotomy in different ways, and it is too early to prescribe ideal solutions.

One consequence is an uncertainty in the future departmental status of scientific computing. This field, once a powerful force in computer development, is in danger of being lost (even in ACAP's classification) between applied mathematics (numerical analysis) and computer science (mathematical software). We see some danger of an isolation of computer science from the other areas in the mathematical sciences. Links between computer science and relevant areas of pure mathematics, especially algebra, and between computer science and applied mathematics, numerical analysis, and statistics all need strengthening.

Because so many of the master's programmes will continue to be specialized, graduate students entering the PhD programmes at Toronto and Waterloo from other universities should normally expect to take additional courses to round out their background.

There appears to be a reasonable balance between the number of computer science graduates and the job market, both at the master's and doctoral levels. Hence we recommend that attention be concentrated on staying in the forefront of current computing research and development, rather than on growth or on the duplication of existing programmes.

University of Toronto

The Department of Computer Science, with the equivalent of about 24 full-time faculty members and 10 or so visitors, is among the best half-dozen in North America. Its graduate courses provide excellent coverage of all major aspects of computing (including programming languages, systems, numerical analysis, the theory of computation, computer architecture, graphics, artificial intelligence, and data base and file management).

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*The Introduction is taken almost verbatim from the preamble of the advisors' report.

The current graduate student body, consisting of about 40 full-time MSc and 45 PhD students, seems to be of good quality and is being well trained and supervised. We understand that no major changes in emphasis or size are being planned for the next five years, and we do not recommend any. The main deficiency noticed was limited interactive computing facilities; we hope this can be remedied. We also hope that the computer science staff will be housed together with the staff of the other mathematical sciences in any new building, so as to foster continued interaction.

Since Waterloo has the only other doctoral programme in computer science in Ontario, cooperation between Toronto and Waterloo in this area seems called for. This would help to avoid the wasteful duplication of expensive facilities. We also urge the University of Toronto to encourage its graduate students to solicit research advice from leading experts in other Ontario universities, especially nearby York and Scarborough, and to include such experts on its doctoral thesis committees whenever appropriate.

Finally, having achieved a high level of quality, the University of Toronto must take special care to maintain it without stagnating during a period of little growth. Great care must be exercised in making new tenure appointments if quality and dynamic flexibility are to be preserved in this rapidly evolving discipline.

Recommendation 30

We recommend:

i) the continuation of the excellent MSc and PhD programmes in computer science at Toronto;
ii) an improvement in interactive facilities;
iii) increased attention to cooperation with the staff of other Ontario universities.

University of Waterloo

The computer science department, with the equivalent of about 30 members of the full-time faculty plus visitors, cross-appointments, etc., is one of the best dozen or so in North America. Its graduate courses cover a wide range of topics, but the department is committed (probably wisely) to only three research areas: computer systems, numerical analysis, and theory of computing, where it is especially strong.

The high reputation of the department is due to its inclusion of a number of individuals who combine originality with scholarship and a high degree of practical know-how. The widely used WATFOR and WATFIV compilers constitute an especially notable achievement, and the excellent computing facilities are smoothly run. However, we think the university should define more clearly the roles of its two independent computing facilities.

We also note with approval the intention of the department to limit the number of new graduate students entering the master's programme to that admitted this year. Moreover, since so many able computer-oriented undergraduates go to Waterloo, we think that a special effort must be made not to starve other master's programmes in Ontario, which might occur if an undue proportion of these undergraduates stay on at Waterloo for their graduate training. As far as doctoral candidates are concerned, cooperation with Toronto in an agreed upon admissions policy would seem desirable.

We hope that limitations of size will make it possible to raise the minimum standards for admission, although we recognize that non-academic qualifications are very important for most jobs. We strongly endorse the orientation of the master's programme towards jobs in business and industry. For this reason, we are especially glad that the faculty considers it unwise to jeopardize the quality of its doctoral programme by giving it a similar orientation.

Recommendation 31

> We recommend that Waterloo continue its graduate programmes, maintaining the size of the present graduate student body and aiming at higher standards if possible.

Carleton University

Computer science at Carleton University is dealt with jointly by the Department of Mathematics and by the Department of Systems Engineering (Faculty of Engineering). The latter group is responsible for undergraduate instruction in computer programming and related topics. The master's degree in most fields of computer science is already offered by one department or the other, with coordination through a joint committee. A plan by the two departments to merge these efforts into a joint MSc programme in Information and Systems Science has reached an advanced stage, having been approved by OCGS in June 1975.

The computer science programme involves 5 faculty members from the Department of Mathematics, mainly in mathematical software and the theory of computation and 14 faculty members from Systems Engineering, mainly in software systems, modelling and computer communications. Most faculty members have a record of published research and are currently holders of research grants.

We do not doubt Carleton's competence to support a satisfactory MSc programme along these lines, and indeed there are already about 40 graduate students enrolled in some aspect of computer science, three quarters of them being part-time students. We are naturally reluctant to criticize the format of a programme so recently externally appraised. Nevertheless there are some aspects that need further consideration.

One is that a close watch should be kept on academic and administrative problems arising from differences between faculties. A second point, mentioned in the statistics section of the report, is that the teaching of statistics and applied probability in the programme should be reviewed. Next, expansion in the number of students enrolled will call for more faculty and the president's letter gives no indication that an additional position is likely to be available. Finally and most importantly, there is the question of cooperation with the University of Ottawa.

While appreciating the useful cooperation that already exists, we think it important that a wide-ranging, high quality programme be developed in the Ottawa area, with particular emphasis on the needs of part-time students. Under present circumstances this is achievable only by positive joint planning by the two universities, and we hope that they will accept the challenge of working out a joint enterprise.

Recommendation 32

We recommend that:

i) the proposed interdepartmental MSc programme in Information and Systems Science should be implemented;
ii) some aspects of this programme should be subject to internal review;
iii) the discussions of long range plans for developing a comprehensive joint programme of academic work in computer science for the Ottawa area should continue under the auspices of a representative ACAP committee;*
iv) in three years time there should be an external appraisal of the graduate programmes in computer science in these two universities.

University of Ottawa

The Department of Computer Science at the University of Ottawa does not have a graduate programme at present, although some faculty participate in the interdisciplinary programme in General Systems and Information Sciences, or supervise graduate students from the Department of Electrical Engineering.

The department has 7 full-time faculty plus another 6 in cross-appointments, these latter contributing about two full-time equivalents. Most of the faculty hold research grants and have developed programmes of personal research; the group is however a new one and this makes it difficult to judge the quality and quantity of research produced.

The department has proposed an MSc programme specializing in the areas of i) mini-computers and micro-computers (systems and applications) and ii) system simulation (methodology, modelling and software).

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*The chairman of this committee should probably not be from either Carleton or the University of Ottawa.

However, a similar programme was not approved in a 1973 appraisal, and we think it would require at least one new faculty member with a substantial publication record to make it viable.

On the other hand, we see a real need for graduate courses attractive to francophone students in Ontario; this is not just a question of the language of formal instruction, but also of the availability of supervisors conversing in the language of the student. Another special need in the Ottawa area is for wide-ranging instruction in computer science with special attention to the needs of part-time students.

We have already discussed this in connection with Carleton University, and repeat our recommendation that Carleton and the University of Ottawa develop a comprehensive programme of study in computer science for the Ottawa area. This should, we think, be a definite ACAP recommendation.

Recommendation 33

We recommend:

i) deferring the establishment of a new master's programme at the University of Ottawa;

ii) that the discussions of long range plans for developing a comprehensive joint programme of academic work in computer science for the Ottawa area should continue under the auspices of a representative ACAP committee;*

iii) any resulting proposal should be submitted for appraisal.

Queen's University

The computer science department has 11 faculty members whose fields of competence cover the subject. There is a quite comprehensive MSc programme with about 35 students, about half of them being part-time. There is usually a thesis, the main component of which is a major programming project. Theses seemed of rather uneven quality. Employment prospects for graduates appear very good; indeed one of the department's problems is that of students who leave before completing their thesis. This is a sound programme and we have no doubt that it should continue.

The department would like to introduce a PhD programme beginning in 1978 and in the fields of programming languages, software systems, data management and information retrieval and applications related to these. Taken as a whole, however, the research output of the department in these fields is not yet impressive. Greater activity is evident in mathematical software and in the special applications that attracted staff into computer science in the first place. Only a minority of the faculty have published more than one paper on computer science in a refereed journal.

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*The chairman of this committee should probably not be from either Carleton or the University of Ottawa.

The plans of the department call for the addition of two members of faculty over the next 5-7 years to support the proposed expansion. We agree that, with the present important commitment to the MSc programme, this expansion is the minimum necessary for a PhD programme. We note that the principal's letter of June, 1975, nowhere refers to such expansion.

Further, there is no strong evidence for the need for a third PhD programme in Ontario in these fields, at least at present.

These considerations have convinced us that it would be premature for Queen's to work on a PhD programme now, and that its computer science faculty should devote their efforts instead to their own research and to strengthening the MSc programme. In another 3 to 5 years, it would seem timely to reconsider the desirability of supplementing the strong existing PhD programmes in computer science at Toronto and Waterloo by other, more specialized PhD programmes.

Recommendation 34

> We recommend that Queen's give attention to continuing to strengthen its MSc programme, before proceeding further with plans for a PhD programme.

McMaster University

The existing MSc programme in computation, established in 1971, emphasizes numerical analysis and optimization. Of the 10 faculty members, four are cross-appointments; five have a PhD in physics. Only one faculty member appears to have a strong interest in theoretical computer science as such.

As an interdisciplinary programme, drawing students from non-mathematical departments, we feel that the present programme may well attract enough Canadian students to be viable. Also, faculty research in optimization and numerical mathematics may be reinforced by substantial research strength in these fields in chemical and electrical engineering. However, it would certainly be desirable to have at least one more faculty member actively working on central problems in computer science.

Recommendation 35

> We recommend that the existing MSc programme be continued, but that its adequacy with respect to core subjects in computer science be reviewed internally whenever a new faculty appointment is made.

University of Western Ontario

There is at present an MSc programme in the Department of Computer Science with 17 full-time students. It has been very successful in preparing students for careers in business and industry. It should certainly continue on the present scale, but we think that raising admission standards would be more desirable than increasing the enrolment to the extent projected.

The department would like to introduce a PhD in a limited number of fields: machine intelligence, operating systems and data structures. An important research tool would be an Interdata 7/32 computer with a TV camera, recently obtained by a major equipment grant from NRC. This proposal has the favourable feature that the challenging field of machine vision is not a specialty of any other Ontario university; moreover the DECsystem 10 at the Computing Centre is particularly well suited to research in artificial intelligence.

However, we do not feel that the research record of the department as a whole is strong enough to justify a new doctoral programme at this time. Technical assistance for faculty members doing research in artificial intelligence need not be provided by research students, and those exceptional research assistants qualified for a PhD in computer science could well obtain the degree under a cooperative arrangement with the Universities of Waterloo and Toronto.

Recommendation 36

> We therefore recommend the continuation of the MSc programme without qualification, but we think that the proposal for a PhD in computer science should be deferred.

University of Guelph

Since the University has withdrawn its proposal for a graduate programme in computer science, no report is required under ACAP guidelines. However, we wish to express our agreement with the chairman's assessment that the potential enrolment in such a programme would be too small to justify the effort. The proximity of Guelph to Waterloo suggests that this situation may not change.

At the same time, we hope that the several faculty members having research interests in the practical aspects of data processing stressed in the good undergraduate programme, data management, simulation, software systems, and business programming languages (COBOL and PL/1), can cooperate in supervising graduate students in other departments or other universities.

We also suggest that, even though the area of specialty is software engineering rather than theoretical computer science, an appointment on the theoretical side might improve the balance of any such programme, as well as adding strength to the present undergraduate programme.

No formal recommendation is called for.

Lakehead University

The University is evolving a proposal for an interdisciplinary MSc programme in applied computer science sponsored by groups in the departments of mathematics, engineering and business. The primary aim would be regional service.

The proposed programme would be run by nine faculty members from the three departments concerned, mostly on a part-time basis and this is perhaps the equivalent of four full-time faculty. In addition, there is some strength in numerical analysis in the Department of Mathematics. Apart from those by the president and his wife, there are very few published research contributions in computer science from the group. The president's letter promises an additional post if the programme is funded.

Since we have not been asked to assess the programme being worked out, we have not done so. However, we do wish to point out the relevance of two of the general observations made in Chapter I: the need to attract enough qualified Canadian students to make an MSc programme viable, and the importance of leaving the faculty enough free time to be active in research.

No recommendation seems called for, since any formal proposal would be subject to appraisal in any case.

York University

York does not have a graduate programme in computer science now, but hopes to have one within two or three years if approval can be obtained. A tentative proposal for an MSc programme was discussed with the ACAP advisors, and is now being revised in the light of this discussion.

The group in the department who have been trying to draft a good proposal are enthusiastic, but none has yet shown great strength in research. Partly for this reason, we think that any proposal that is generated should involve cooperation with the University of Toronto. Increased collaboration between the Faculty of Arts and Atkinson College might also help with the heavy undergraduate programme. One possibility would be an MSc programme aimed at part-time students, partially duplicating courses given at Toronto. Another would be occasional participation by York faculty in the work at Scarborough.

Recommendation 37

We recommend that:

i) any proposal put forward for detailed appraisal should specify the collaboration involved with the University of Toronto;

ii) before a proposal is put forward for an independent programme, two new faculty appointments should be made.

CHAPTER III

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. Introduction

In this part of our report we draw together our discussion of and recommendations about some general issues. There is some overlap with the earlier parts of the report. The points come under three broad headings: collaboration between universities (section III-2, III-3, and III-4); matters connected with specific mathematical or academic issues (sections III-5, III-6, III-7, III-8); and matters more of an administrative or service nature (sections III-9, III-10, III-11, III-12). Our discussion has to be taken in the context of the important recommendation in section I-6 that the number of PhDs awarded each year in the mathematical sciences should be approximately 40, 10 for each area.

2. Interuniversity arrangements

In our detailed recommendations for individual universities we have mentioned a few special cases where increased collaboration over course work is desirable. Here we discuss some of the wider issues involved. First some general points need to be made.

We applaud the appreciable collaboration that already takes place, notably in arranging such events as "algebra days" and in joint arrangements for visiting seminar speakers. In suggesting the need for further collaboration we appreciate the difficulties involved and the suggestions that follow are intended for implementation by mutual agreement among faculty members; such an arrangement is much more likely to be effective than one imposed by an outside body.

We realize that chairmen of departments meet informally. We suggest a rather more formal arrangement to examine matters of mutual interest, an interuniversity committee of the mathematical sciences, possibly the ACAP Discipline Group. This could, we hope with the minimum of administrative formality, deal with a number of matters of mutual concern, some listed below. The committee would require subsections for the four areas; at most, two people from one university should attend any given subsection meeting.

The interuniversity committee would, we suggest, deal with the following things, among others:

i) library matters (see section III-10), and

ii) the preparation at least every two years of a booklet about graduate work in Ontario in the mathematical sciences (see recommendation 38). The booklet should contain general advice and information to potential graduate students, information about fields of study (see section III-8) and a factual statement of four pages maximum from each university offering a graduate programme. The booklet should be distributed widely to undergraduates in Ontario and we hope throughout Canada and internationally.

There are two other important issues connected with interuniversity collaboration. The first concerns active research groups with few or no research students. We were glad to hear that arrangements are widespread whereby a faculty member at one university can be the research supervisor of a student elsewhere, but we appreciate that this is bound to be a fairly exceptional arrangement. We consider, however, that the advisory committee for the work of every research student should contain at least one person from another university. Where that person is not the principal advisor there should be contact with the student's work at least every six months. We see this as a way of using the appreciable expertise at universities with small numbers of research students and, equally importantly, of giving younger faculty members at such universities some experience of research supervision.

Finally we point out the possible advantages of collaboration where two universities with fairly similar interests have master's programmes of only just viable size; in particular, it may be possible to alternate years of entry, the master's programmes being planned towards doctoral work at either university.

Arrangements for joint seminars and for exchange of information about visitors should be systematized. Also arrangements should be encouraged for students, especially doctoral students near the end of their work, to meet fellow students from other universities for discussion of their work. Our impression is that while students sometimes travel to other universities to hear visiting seminar talks, they rather rarely have useful scientific contact with students from other universities.

Recommendation 38

We recommend that:
a suitable interuniversity committee of the mathematical sciences should

i) produce every two years a booklet describing graduate work in the mathematical sciences in Ontario;
ii) review library matters of joint interest;
iii) ensure that advisory committees of research students contain at least one member from another university;

iv) ensure that arrangements are universal whereby a research student at one university is permitted to have as his principal advisor a faculty member from another university.

3. Critical size of programmes

The ACAP specification calls for general discussion of the size of programmes and we turn to this now; it has a direct bearing on the relations between universities and interuniversity collaboration. The considerations are somewhat different for master's programmes involving much course work and for doctoral programmes, where quality of the research supervision is of overwhelming importance.

Size of programmes is most relevant in those aspects of computer science where expensive and specialized hardware is involved, but a much more flexible attitude is needed towards work in pure and applied mathematics and in statistics.

There is no reason in principle why research of distinction should not be done by a research student working as the sole research student attached to a group of faculty active in research or even to an individual faculty member of distinction; library and computing facilities are entirely adequate in all the universities visited to support such students. The quality of faculty supervision provided is the crucial thing, especially in so far as it affects the choice of topics for study. For course work at both master's and doctoral levels, there will be much less choice of specialized topics in university departments with small total numbers of graduate students, but there are in such departments compensating aspects of increased breadth, arising also from increased contacts with students in other branches of mathematics. We must report also that more than once in our visits we heard very eloquent defences of small departments from students who had been graduate students earlier in larger departments; of course, this does not prove that their training was better in the smaller department!

However, we have no doubt that by and large, in all the areas, and taking a world-wide view, the most significant work is done by students working in centres where there are appreciable numbers of students and faculty active in research in the topic in question. The location of these key centres can, however, shift quite rapidly, a fact which is itself another argument against a rigid allocation of research students to a few centres; at least any such allocation would need frequent review. See also our comments in section II-B on rapid changes of interest within applied mathematics.

To summarize, we consider that most research students should work in centres where there are an appreciable number, five or more research students in their area, but that other departments with the facilities to provide programmes of the necessary quality should not be barred from doing so. It is important and just that students choosing their university of study should be aware of the issues involved. Further, where a student is on his own, or one of a very small group, the department should be under a strong obligation to ensure contact with other universities, attendance at seminars, etc.

The postgraduate booklet (see section III-2) should therefore contain a prominent statement similar to the following: "It is entirely possible for a student to obtain guidance of distinction within departments with a very small number of graduate students. Nevertheless it is true internationally that most research work of high quality is found within departments having a number of faculty active in the area in question and having associated with them five or more graduate students. Such an environment, at its best, produces an invigorating atmosphere, including discussion between students working on related problems and a good choice of relevant course work."

Some but not all of the above discussion applies also to master's programmes, in which the course work element is predominant. There, however, it is not economically viable to mount a thorough programme of course work within an area without a good number of students. We have made comments, where appropriate, on individual universities in Chapter II.

Recommendation 39

> We recommend that the postgraduate booklet should show the numbers of master's and doctoral students working in each university in the various areas, and should contain a prominent statement that the size of the group is a relevant consideration in deciding where to apply.

4. Movement of students between universities

Students choose their university of study on a variety of grounds. We recognize, of course, that there may be compelling personal reasons for a student remaining in one geographical area; this applies particularly, but not only, to Lakehead and Windsor. Also students may wish to continue the doctoral work with an advisor whose work has interested them at undergraduate or master's level. Nevertheless the academic and personal arguments for not doing all three of undergraduate, master's and doctoral work in the same place are strong.

In most cases a move should be made at the start of postgraduate work. We appreciate the difficulties of effective action on this. Financial incentives to students to move universities can be envisaged. However, there are special fields where the expertise for supervision of research may be concentrated in one university.

Recommendation 40

We recommend that:

i) the booklet on graduate work should contain a strong statement about the advantages of having worked in more than one university;

ii) those advising fourth year undergraduates should feel obliged to point out the advantages of a move;

iii) the interuniversity committee should produce and circulate each year statistics for each university of the numbers of Canadian and non-Canadian master's and doctoral students registered and the number of those who have studied only at the university in question.

5. Part-time students

We now turn to a number of issues of a more specifically academic or mathematical character and first discuss the considerable importance of master's work for part-time students, especially in statistics and computer science.

Graduate work in the mathematical sciences is inevitably specialized, calls for very concentrated work, and therefore the role of courses for part-time students is largely limited to situations where there is substantial connection with the students' employment. We see however a very important role for part-time master's courses in statistics and computer science and in appropriate fields for school teachers. We were glad to see proposals for such courses, from the main population centres.

We have the following general comments.

a) The general academic standard of such courses should not differ substantially from that of courses for full-time students, although the content may well be different.

b) Some courses for school teachers should include statistics and computing. There is likely eventually to be considerable scope for imaginative teaching of these in schools, given suitably qualified teachers.

c) In particular areas there may be scope for more specialized master's work, for example in actuarial science.

d) There may be some demand for short intensive "post-experience" courses on specialized topics for workers in industry, government and business, but we take discussion of these as outside the terms of reference of the present report.

e) We have seen no proposals for doctoral work, based solely on part-time study, and we do not wish to encourage any.

Recommendation 41

We recommend that:

i) part-time master's courses including statistics and computer science should be encouraged in the main population centres. They should be at the same academic standard as corresponding courses for full-time students;

ii) courses for school teachers should be broad and also include the opportunity to study statistics and computing.

6. Mathematical work in other departments

A recurring theme discussed in section II-B, applied mathematics and in section II-C, statistics, has been the difficulty in assessing the amount and quality of mathematical work in other departments, most notably but by no means entirely, in departments of physics and engineering. In our visits to universities we heard of many examples of such work and of encouraging collaboration between mathematicians in various departments. Joint programmes are an excellent idea but difficult to administer. There is need also for small meetings of scientists in fields with relatively novel mathematical problems together with mathematicians with a variety of special interests. As explained in section II-B such activities are especially desirable to invigorate applied mathematics.

Recommendation 42

We recommend that regulations allowing joint supervision of research students by staff in more than one faculty should be encouraged.

7. Comprehensive doctoral requirements

Preliminary qualification for doctoral candidacy is in essentially two parts. The first, concerned with the special field proposed for research, raises no general issues. The second, the establishment of broad mathematical education, does raise some awkward points, especially for students in the more applied subjects.

It is excellent that some students working in numerical analysis, statistics, applied probability, the mathematics of operations research, etc., should have a good knowledge of topics of pure mathematics not commonly used in the field proposed for research. It is at least equally important that many students even if working in very theoretical areas, should have non-superficial experience of applications; students working on the numerical solution of partial differential equations should know something about some aspects of continuum physics. We are concerned that the general comprehensive requirements are sometimes those for work in pure mathematics, regardless of the ultimate field of research; in other cases the requirements may be too rigidly those for work in classical applied mathematics. Of course, we do not suggest that every thesis in more applied areas has to be judged by its immediate usefulness in applications. We suggest a more flexible and interdisciplinary content in the comprehensive requirements.

We think also, both on scientific grounds and on grounds of social usefulness, that graduate students in pure mathematics should be advised to follow at least one applied topic to a reasonably advanced level (see section II-A).

Recommendation 43

We recommend that:

i) comprehensive requirements for students in applied subjects should be broader and more flexible. They should include the possibilities, both of studying pure mathematics to an advanced level and of making a deep study of applications;

ii) graduate students in pure mathematics should be advised to study some applied topic.

8. Topics for research

We consider the general balance that has been reached in Ontario between the four areas of pure mathematics, applied mathematics, statistics, and computer science to be very reasonable and nothing further need be said about this. The following comments refer rather to the choice of particular topics and fields within the four areas.

Mathematical work is very specialized and we do not think it at all necessary that the balance of subjects studied by research students in Ontario should conform to world-wide interests. Nevertheless it is undesirable that appreciable proportions of students should work in very narrow fields; this applies particularly to pure mathematics, but to some extent also to the other areas. In any case, a very narrowly educated doctoral student is often a poor teacher and difficult to place in fruitful employment.

We do not favour the imposition of rigid quotas for numbers of students entering the various special topics, although we have in Chapter II indicated desirable numbers of doctoral students in the four areas. We do, however, think that it is right for faculty and potential research students to know how many students are in the various special topics over the province. The number of students in the various areas should be monitored by the inter-university committee.

The ACAP requirements specifically ask for comments on topics inadequately covered. This is difficult to assess, particularly because in say, ten years, there can be appreciable changes of emphasis, both in the research interests of particular individuals and departments, and in the fields in which internationally the most exciting work is being done. This is particularly relevant in applied mathematics; see section II-B.

There is some weakness over the province in applied probability and this is illustrated in the following three special cases.

We found no really deep involvement in the mathematical techniques of operations research and management science, including inventory control, production scheduling, reliability, etc. There is a very strong department of combinatorics at Waterloo, but there the contact with applications did not seem very great. We realize, however, that much work is in progress in management science and engineering departments and that isolated individuals in mathematics departments have very useful involvement in such work. We found, for example, no place where the statistical aspects of simulation are studied despite their wide importance.

The absence of a strong group in a mathematics department interested in both deterministic and stochastic control theory is striking. Again we were unable to see in detail work in engineering departments.

We were glad to see developing in several universities an interest in mathematical biology, including ecology. Again the deterministic aspects seemed to predominate over the stochastic. While we had not the time to discuss this in detail, we wonder whether the deep level of collaboration between mathematicians and biologists necessary for such work to be scientifically fruitful is widely appreciated. More joint work between mathematics and biology departments at the undergraduate level may be required to produce research students with the right background; see section III. Review of comprehensive doctoral requirements to foster joint work is also important; see section III-7.

We consider that there should be more emphasis on the unified study of numerical mathematics. We realize that it is arguable that this subject is best regarded as a series of more or less unrelated parts, primarily

numerical linear algebra
numerical solution of ordinary differential equations
numerical solution of partial differential equations
numerical solution of integral equations
numerical optimization
numerical analytical aspects of statistics

but we feel that some unity should be aimed at especially in teaching, but also in strengthening research.

We found no strong centre of work on the computational aspects of statistics.

The ACAP investigation has been based on a somewhat artificial division into four areas. The need for individuals to change interests usually but not necessarily from the relatively pure to the relatively applied is widely recognized and we were glad to see such shifts of interest among faculty being encouraged in many departments. We have no specific recommendations about how such changes are to be further helped, but note the following groups of subjects where increased mixing of ideas and specialities is likely to be fruitful;

probability - functional analysis;
statistics, and applied stochastic processes - numerical analysis;
deterministic problems in mathematical biology, as treated by
  experts in differential equations, etc. - stochastic problems;
algebra - mathematical biology;
applied mathematics - computer science.

We make no specific recommendations on the detailed topics just discussed; see, however, the general recommendations on applied mathematics, section II-B. To complete the section we restress the importance of making relevant information on fields of activity widely available.

Recommendation 44

We recommend that:

i) the interuniversity committee should every few years review topics of especial promise in which fewer students are working than is desirable, the objective being a shift of emphasis from thesis topics of a highly specialized character to those of a broader and interdisciplinary kind;

ii) the interuniversity committee should provide in the graduate booklet information both on the numbers of completed theses, for each of the main special topics, and on thesis titles and supervisors.

9. Administrative matters

While administrative matters as such are outside our terms of reference, some brief comments are in order. These concern a) arrangements between different faculties, b) general financial arrangements between departments within the mathematical sciences, and c) arrangements within departments.

Mathematics is in some senses intermediate between the Faculty of Arts and the Faculty of Sciences, computer science is intermediate between the Faculty of Science and the Faculty of Engineering; there are wide applications of mathematics in engineering and increasing interests in medicine. It was our impression at more than one university that overrigid distinctions between faculties inhibited cooperation in the training of students. Further, some faculty believe that money is allocated to departments rigidly on the basis of BIU's in different ways for different faculties, though we had a strong positive impression of deans' anxiety to ensure fair distribution of resources and high academic standards. The above belief, whether true or not, can inhibit needed collaboration.

On b), there is no single answer to the question whether there should be separate departments of pure mathematics, applied mathematics, statistics and computer science; flexibility and variety should prevail and the size of the groups is important. Nevertheless we are very concerned at situations where students especially in numerical analysis, applied analysis, probability and statistics may be in one of two or more departments and, depending on their department, are subject to quite different regulations and separated from students with similar interests. We have commented individually on some specific instances where the departmental structure needs reconsideration.

As regards c), concerning individual departments, it will be appreciated that we spent too short a time in any one department to comment sensibly on the administrative arrangements. We report, however, a general impression that excessive time is spent in committee work. Fairness demands that someone doing a large amount of administration should, if they wish, have a somewhat reduced teaching load, but such allowances should, in our opinion be confined to a very few people in each department. Special recognition and encouragement of research contributions is more important, and ways of doing this should be considered.

10. Libraries

The original ACAP proposal called for a report by a special library advisor. Therefore, on their visits to the universities, the mathematics advisors and consultants confined their investigation of library facilities to brief visits to libraries and to questions to faculty and students. In fact, when these visits were complete ACAP decided, with the agreement of the consultants and advisors, not to appoint a special library advisor and to rely on the visits already made. Thus the following comments are made after a much less thorough study than was first intended. We were, of course, in the time available quite unable to examine the important issues of library financing, including the proportion of library funds spent on books and journals.

Our main general conclusion is that in all universities visited a high general standard of library service appeared to be available.

There are the following more detailed comments:

a) The interlibrary loan service is effective, although there were complaints from some universities, especially from students, about slowness. We were not able to investigate these complaints, but we consider that departments should provide some mechanism for so doing.

b) Most departments have committees or individuals who take a special interest in the library and we commend this arrangement. This should be the route for investigating complaints under (a); a regular report should be made to departments of the distribution of the time between ordering books and their being available for loan.

c) Many faculty members are alarmed that financial stringency may make it difficult to take new journals and that subscriptions to established journals may have to be cancelled. We do fully endorse the very great importance of rapid access to the central journals for fields in which research is active, but consider it only realistic to recognize that for the less central journals increased sharing of resources and the use of library systems are inevitable. It is, therefore, very important that acquisitions should be planned by the department concerned on a regional basis and we recommend that the interuniversity committee should examine this question to ensure that there are copies in Ontario of even minor journals. Such devices as the circulation of content pages of journals not taken at the university in question should be provided where there is a clear need. It is important that books should be available for loan soon after publication, but blanket ordering of books is not defensible when money is short. While we were impressed by the initiative shown by several university libraries in implementing computer systems for abstract retrieval, etc., we would, however, deplore a significant proportion of library funds being spent in this way, at the expense of the acquisition of books and journals.

Recommendation 45

We recommend that:

i) departments should have a library officer or committee responsible for recommending books and journals for purchase, checking the efficiency of the interlibrary loan scheme and reporting to colleagues on the speed with which new books become available for loan;

ii) the interuniversity committee should, if the need arises, examine and ensure the circulation of information about new and relatively obscure journals;

iii) faculty should cooperate in interuniversity schemes of coordinated library services.

11. Computer services

Detailed investigation of computer services was outside our terms of reference; nevertheless brief visits were paid to computer centres. Our general impression of the services provided was extremely favourable. Programming advisory services were judged effective by faculty and students whom we questioned and the availability of library programmes appeared very satisfactory.

It is important that computer centres should have close links with mathematicians and other specialists to ensure that

a) full advantage is taken of current developments, for example by maintaining on-line the best available numerical analytical and statistical packages,

b) specialized problems are, where appropriate, referred to a suitable specialist, particularly in numerical mathematics and statistics, but also in other areas, arising, for example, in the work of the programme advisory service.

The important and difficult questions of the cost of computer services and of the proportion of a university's effort that should be devoted to such services are similar to those for libraries. We were not supplied with data which could be the basis for a rational discussion of this.

Recommendation 46

We recommend that directors of computer centres should review periodically the adequacy of their collaboration with numerical analysts, statisticians and others with applicable expertise.

LIST OF RECOMMENDATIONS

Recommendation 1: Employment opportunities and limitations on enrolments

We recommend that:

i) the enrolment statistics be regularly monitored by the discipline group in the mathematical sciences, and if excessive fluctuations, either up or down, occur that remedial action be initiated;

ii) the number of PhDs in mathematical sciences awarded by the Ontario universities total about 40 per year, with about 10 from each of the four areas;

iii) that the figures given in ii) be reconsidered for possible modification at regular intervals in the future.

(see A-25)

PURE MATHEMATICS

Recommendation 2: University of Toronto

We recommend that:

i) the space available for the mathematical sciences be increased and centralized;

ii) the MSc and PhD programmes of the department should be continued;

iii) about 5 PhDs in pure mathematics per year should be produced;

iv) the whole programme of graduate work in pure mathematics should be reconsidered within the department.

(see page A-33)

Recommendation 3: University of Waterloo

We recommend that:

i) there should be a uniform qualifying examination for intending doctoral candidates in pure mathematics including those in the Department of Combinatorics and Optimization;

ii) the MMath, MPhil and PhD programmes continue to strengthen their minimum standards;

iii) about three PhDs per year should be produced in the pure mathematics area at Waterloo.

(see page A-34)

Recommendation 4: Carleton University

We recommend that:

i) the MSc programme continue;

ii) about one PhD a year should be produced in the pure mathematics area at Carleton.

(see page A-35)

Recommendation 5: University of Ottawa

We recommend that:

i) the proposed MAT programme should be developed;
ii) the MSc and MA programmes should continue;
iii) the doctoral programme in pure mathematics should continue for two years after which its viability should be subject to external appraisal.

(see page A-36)

Recommendation 6: Queen's University

We recommend that the MA, MSc and PhD programmes should continue at their present level.
(see page A-36)

Recommendation 7: McMaster University

We recommend that:

i) the MSc programme should continue;
ii) steps should be taken to make the analysis section of the PhD programme more in line with current interests and applications;
iii) subject to ii), the PhD programme should continue aiming to produce one or two PhDs per year.

(see page A-37)

Recommendation 8: University of Western Ontario

We recommend that:

i) the MA programme should continue;
ii) efforts should be made to broaden the PhD programme. In the meantime the programme should continue for two years, after which its viability should be reappraised externally.

(see page A-38)

Recommendation 9: University of Windsor

We recommend that the PhD programme in pure mathematics be reappraised for its viability after two years, along with those of the University of Ottawa and the University of Western Ontario.
(see page A-39)

Recommendation 10: Lakehead University

We recommend that Lakehead University should be encouraged to submit for appraisal a programme for a master's in mathematics unrestricted in scope and covering a degree by course work or thesis.
(see page A-41)

Recommendation 11: York University

We recommend that:

i) the MA programme should continue;

ii) special efforts should be made to involve York faculty in the supervision of research students at other universities, especially the University of Toronto;

iii) the location of the Department of Mathematics vis-a-vis the Faculty of Arts and other faculties and colleges should be reviewed by the University.
(see page A-42)

APPLIED MATHEMATICS

Recommendation 12: Introduction

We recommend that:

i) there is a general need for reexamining the role of applied mathematics;

ii) further, there will be a need for continuing reappraisal, with attention to research and training in applications with good employment prospects in Ontario and Canada;

iii) to ensure genuine contact with applications much greater use of interdepartmental appointments is desirable.
(see page A-45)

Recommendation 13: University of Toronto

We recommend that an internal interdisciplinary committee, sympathetic to applied mathematics, reconsider Toronto's role in this area. Such a committee might well recommend the formation of an independent department.
(see page A-46)

Recommendation 14: University of Waterloo

We recommend, with the preceding considerations in mind, a continuation of the MMath and PhD programmes at Waterloo, but with increased emphasis on areas in which there exist non-academic job opportunities. We also recommend that, in the near future, new appointments be made of faculty whose research is concerned with such areas.
(see page A-47)

Recommendation 15: Carleton University

We recommend that:

i) Carleton University continue to develop its interdepartmental MSc programme in Information and Systems Science and examine the possibility of a cooperative programme in this field with the University of Ottawa:

ii) the areas in which the PhD in applied mathematics is offered be more precisely defined.
(see page A-47)

Recommendation 16: University of Ottawa

We recommend that the University of Ottawa be encouraged:

i) the develop an interdepartmental MSc programme in mathematical economics;

ii) to examine the possibility of a cooperative programme in the field of information and systems science with Carleton University.
(see page A-48)

Recommendation 17: Queen's University

We recommend continuation of the existing MA, MSc and PhD programmes in applied mathematics at Queen's University, but with increased emphasis at the master's level on applications associated with non-academic employment opportunities.
(see page A-49)

Recommendation 18: University of Western Ontario

We recommend that the University of Western Ontario continues its strong programme in applied mathematics, turning out an occasional PhD. Any other recommendations must be deferred until after existing committees have succeeded in resolving internal problems.
(see page A-50)

Recommendation 19: University of Windsor:

We recommend a continuation of these programmes, but with an internal review in the near future of non-academic employment opportunities for graduates of the doctoral programme.
(see page A-50)

STATISTICS

Recommendation 20: University of Toronto

We recommend that:

i) there should be a reorganization as soon as possible of the whole of statistical work in the university;
ii) in the meantime the graduate programmes should continue;
iii) there should be a regular statistical seminar involving some collaboration with York University.
(see page A-55)

Recommendation 21: University of Waterloo

We recommend that:

i) current graduate programmes should be continued and developed in the way proposed by the university;
ii) arrangements for "consulting" work with other departments should be strengthened; there should be increased collaboration, in particular with the University of Guelph and other nearby universities.
(see page A-56)

Recommendation 22: Carleton University

We recommend that:

i) the MSc and PhD programmes continue in accordance with the university's plan;
ii) the cooperative programme should be strongly encouraged;
iii) the role of statistics and probability in the MSc in Information and Systems Science should be given an internal review;
iv) there should be increased collaboration with the statisticians at the University of Ottawa.
(see page A-57)

Recommendation 23: University of Ottawa

We recommend that:

i) the programme of the group should be appraised within three years;
ii) there should be increased collaboration with statisticians at Carleton University.
(see page A-58)

Recommendation 24: Queen's University

We recommend that:

i) present graduate programmes should continue;
ii) the STATLAB should be strongly encouraged;
iii) the breadth requirements for the PhD should be reviewed;
iv) the statistics group should have more autonomy.
(see page A-58)

Recommendation 25: McMaster University

We recommend that:

i) there should be a reorganization of statistical work into a more unified form;

ii) there should be an external reappraisal of work in probability and statistics within three years;

iii) in the meantime the present joint MSc programme and the PhD in probability under pure mathematics should continue.

(see page A-59)

Recommendation 26: University of Western Ontario

We recommend that there should be an external appraisal of the whole programme to examine, in particular, the criticisms listed above.

(see page A-60)

Recommendation 27: University of Windsor

We recommend that:

i) additional research-oriented appointments are essential;

ii) the MSc and PhD programmes should continue as proposed;

iii) additional contact with other universities is very important and should be developed.

(see page A-60)

Recommendation 28: University of Guelph

We recommend that:

i) the master's programme continue in accordance with the university's plan;

ii) there should be emphasis on biological statistics;

iii) a new faculty appointment should put strong emphasis on research and that the fields of applied probability and biological statistics are particularly appropriate;

iv) an interuniversity seminar should be instituted.

(see page A-61)

Recommendation 29: York University

We recommend that:

i) the part-time graduate programme at the master's level should be further developed;

ii) consideration should be given to a master's programme in applied probability;

iii) there should be substantially increased collaboration with University of Toronto.

(see page A-62)

COMPUTER SCIENCE

Recommendation 30: University of Toronto

We recommend:

i) the continuation of the excellent MSc and PhD programmes in computer science at Toronto;
ii) an improvement in interactive facilities;
iii) increased attention to cooperation with the staff of other Ontario universities.
(see page A-64)

Recommendation 31: University of Waterloo

We recommend that Waterloo continue its graduate programmes, maintaining the size of the present graduate student body and aiming at higher standards if possible.
(see page A-65)

Recommendation 32: Carleton University

We recommend that:

i) the proposed interdepartmental MSc programme in Information and Systems Science should be implemented;
ii) some aspects of this programme should be subject to internal review;
iii) the discussions of long range plans for developing a comprehensive joint programme of academic work in computer science for the Ottawa area should continue under the auspices of a representative ACAP committee;
iv) in three years time there should be an external appraisal of the graduate programmes in computer science in these two universities.
(see page A-66)

Recommendation 33: University of Ottawa

We recommend:

i) deferring the establishment of a new master's programme at the University of Ottawa;
ii) that the discussion of long range plans for developing a comprehensive joint programme of academic work in computer science for the Ottawa area should continue under the auspices of a representative ACAP committee;
iii) any resulting proposal should be submitted for appraisal.
(see page A-67)

Recommendation 34: Queen's University

We recommend that Queen's give attention to continuing to strengthen its MSc programme, before proceeding further with plans for a PhD programme.
(see page A-68)

Recommendation 35: McMaster University

We recommend that the existing MSc programme be continued, but that its adequacy with respect to core subjects in computer science be reviewed internally whenever a new faculty appointment is made.
(see page A-68)

Recommendation 36: University of Western Ontario

We therefore recommend the continuation of the MSc programme without qualification, but we think that the proposal for a PhD in computer science should be deferred.
(see page A-69)

Recommendation 37: York University

We recommend that:

i) any proposal put forward for detailed appraisal should specify the collaboration involved with the University of Toronto;
ii) before a proposal is put forward for an independent programme, two new faculty appointments should be made.
(see page A-71)

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Recommendation 38: Interuniversity arrangements

We recommend that:
a suitable interuniversity committee of the mathematical sciences should

i) produce every two years a booklet describing graduate work in the mathematical sciences in Ontario;
ii) review library matters of joint interest;
iii) ensure that advisory committees of research students contain at least one member from another university;
iv) ensure that arrangements are universal whereby a research student at one university is permitted to have as his principal advisor a faculty member from another university.
(see page A-73)

Recommendation 39: Critical size of programmes

We recommend that the postgraduate booklet should show the numbers of master's and doctoral students working in each university in the various areas, and should contain a prominent statement that the size of the group is a relevant consideration in deciding where to apply.
(see page A-75)

Recommendation 40: Movement of students between universities

We recommend that:

i) the booklet on graduate work should contain a strong statement about the advantage of having worked in more than one university;
ii) those advising fourth year undergraduates should feel obliged to point out the advantages of a move;
iii) the interuniversity committee should produce and circulate each year statistics for each university of the numbers of Canadian and non-Canadian master's and doctoral students registered and the number of those who have studied only at the university in question.
(see page A-76)

Recommendation 41: Part-time students

We recommend that:

i) part-time master's courses including statistics and computer science should be encouraged in the main population centres. They should be at the same academic standard as corresponding courses for full-time students;
ii) courses for school teachers should be broad and also include the opportunity to study statistics and computing.
(see page A-77)

Recommendation 42: Mathematical work in other departments

We recommend that regulations allowing joint supervision of research students by staff in more than one faculty should be encouraged.
(see page A-77)

Recommendation 43: Comprehensive doctoral requirements

We recommend that:

i) comprehensive requirements for students in applied subjects should be broader and more flexible. They should include the possibilities, both of studying pure mathematics to an advanced level and of making a deep study of applications;
ii) graduate students in pure mathematics should be advised to study some applied topic.
(see page A-78)

Recommendation 44: Topics for research

We recommend that:

i) the interuniversity committee should every few years review topics of especial promise in which fewer students are working than is desirable, the objective being a shift of emphasis from thesis topics of a highly specialized character to those of a broader and interdisciplinary kind;

ii) the interuniversity committee should provide in the graduate booklet information both on the numbers of completed theses, for each of the main special topics, and on thesis titles and supervisors.

(see page A-80)

Recommendation 45: Libraries

We recommend that:

i) departments should have a library officer or committee responsible for recommending books and journals for purchase, checking the efficiency of the interlibrary loan scheme and reporting to colleagues on the speed with which new books become available for loan;

ii) the interuniversity committee should, if the need arises, examine and ensure the circulation of information about new and relatively obscure journals;

iii) faculty should cooperate in interuniversity schemes of coordinated library services.

(see page A-82)

Recommendation 46: Computer services

We recommend that directors of computer centres should review periodically the adequacy of their collaboration with numerical analysts, statisticians and others with applicable expertise.
(see page A-83)

Appendix I

Procedure for Mathematical Sciences Planning Assessment

20 December, 1974

A - Interpretation

This document uses several words in specialized senses. These meanings follow.

Acronyms:	COU - Council of Ontario Universities OCGS - Ontario Council on Graduate Studies, an affiliate of COU. ACAP - Advisory Committee on Academic Planning, a committee of OCGS, established by By-Law No. 3 of OCGS. CDAS - Council of Deans of Arts and Science, an affiliate of COU.
Advisor:	A mathematics expert whose functions are explained below; there are two advisors for each area.
Appraisal:	A procedure leading to a decision as to whether or not the quality of a programme is or will be adequate; the universities have agreed not to begin new programmes without first obtaining an appraisal and not to add new fields to existing programmes without referral to the Appraisals Committee to decide if an appraisal is required.
Appraisals Committee:	A committee of OCGS, established by By-Law No. 2 of OCGS.
Area:	One of the four divisions of the mathematical sciences used in this planning assessment, viz. pure mathematics, applied mathematics, statistics, computing science.
Consultant:	One of three persons who are consultants to ACAP and whose functions are described more fully below; they are aided by "advisors."
Discipline Group:	Refers to the Mathematical Sciences Discipline Group, constituted as authorized by OCGS on 15 November 1974. See Appendix I.
Graduate Programme:	The word "programme" is used to signify all aspects of the graduate undertaking of a department (or institute, etc.),

including the actual and planned faculty strength, extent and limitations of areas of research specialization, research facilities, and curriculum.

Planning Assessment: A formal review of current and projected graduate programmes within a discipline or a group of disciplines, in this case within the mathematical sciences and embracing the four "areas" listed above.

Reports: Four types of reports are referred to and described in this procedure:

a. An Area Report, written by area advisors and submitted to the university concerned, the consultants, and ACAP.

b. The Consultants' Report, written by the consultants and submitted to ACAP, and dealt with as described in Section G2.

c. The ACAP Report, written by ACAP and submitted to COU. A draft form is first provided for comment to universities and to the Discipline Group.

d. The COU Report, containing COU's recommendations to the Ontario Council on University Affairs and to the universities.

Field: Each of the four areas is further subdivided into fields.

University Plan: Denotes the official statement made by a university in accordance with paragraphs C7 and C8 below.

B - Choice of Consultants and Advisors

B1. There shall be three consultants, two of whom shall be mathematicians of international standing with breadth of outlook on the mathematical sciences and with suitable administrative or consulting experience. The third consultant shall be a person of wide academic experience in Canada but not in mathematics. No consultant shall be on the permanent staff of an Ontario university.

B2. ACAP shall call the Discipline Group together to discuss the choice of consultants and to nominate a list of about ten potential consultants. If it seems desirable, ACAP may also propose names, but they shall be approved by the Discipline Group.

B3. From the resulting list, ACAP shall select its consultants.

B4. There shall be eight advisors, two for each area. Each advisor shall be an acknowledged expert in the relevant area and at least one advisor in each area shall have extensive experience with graduate work. No advisor shall be on the staff of an Ontario university.

B5. The Discipline Group shall establish four ad hoc area subcommittees for the purpose of proposing names of potential advisors for each of the four areas. Each subcommittee shall consist of persons who work in the area in question and there shall be one member from each university that proposes to offer graduate work in the area; in so far as possible the members of the subcommittees shall be members of the Discipline Group. Each subcommittee shall meet with an ACAP representative to discuss the choice of advisors and to prepare a list of at least eight nominations. These nominations shall be submitted to ACAP through the Discipline Group which may comment on the choices.

B6. ACAP shall select the advisors from these lists, and may obtain help from the consultants in doing so.

C - Collection of Data and of University Plans

C1. ACAP staff will prepare draft forms and instructions for collection of data as described in paragraph C6. The Discipline Group will examine and comment on these forms and instructions, in particular on the choice of fields.

C2. After the forms have been completed by the universities, the Discipline Group will examine the data supplied, and indicate any inadequacies or inconsistency of reporting standards.

C3. The Discipline Group will consider and discuss also the university plans submitted. The Group may make suggestions to an individual university or to ACAP as a result of these discussions.

C4. If the discussions of C3 were to lead a university to modify its plans, it would so notify ACAP.

C5. If a university changes its plans at any time before the completion of the planning assessment, it shall notify ACAP of the changes. Consultants are instructed to disregard any material provided to them which is at variance with the statements provided by the university through ACAP.

C6. Each university is to supply to ACAP (in the form decided following procedure C1) the following information:

(a) the areas and fields currently offered for master's and doctoral work

(b) for each area and field current lists of faculty members, numbers of faculty members, enrolments, degrees granted and drop-outs in previous years

(c) curricula vitarum of all faculty members now engaged in graduate instruction or soon expected to be

(d) historical data on graduate students covering,

    (i) enrolment
    (ii) immigration status and country of first degree
    (iii) financial support
    (iv) drop-out number
    (v) degrees granted
    (vi) post-graduation employment of PhDs
    (vii) employment of ABDs
    (viii) list of doctoral thesis topics

(e) data on the undergraduate base, in particular enrolment in work leading to graduate study

(f) data and statements on resources of space and laboratory and computing facilities

(g) data and statements on library resources, in a form to be worked out in conjunction with the Office of Library Coordination

(h) support from related departments

(i) inter-university arrangements for graduate study in mathematical sciences

C7. Each university is to supply to ACAP a statement of its plans for the future of graduate work in the mathematical sciences, in as much detail as possible, under each of the headings (a), (b), (f), (g), (h) and (i) in C6, including explicitly the planned numbers of faculty and graduate students in each area for the next five years. The plans shall treat the years 1975-1980 in detail and should look ahead to about 1985 in outline. The plans should be accompanied by arguments supporting their appropriateness and should consider the projected enrolments in terms of the sources and motivations of potential students. Since the consultants are to deal with changes in the field emphasis and in methods and content of mathematical graduate education, any plans bearing on these topics should be presented. It is expected that the plans presented in response to this procedure (C7) will be largely generated at the departmental level, and may contain components on which the university cannot comment at this time; the statement shall however be submitted by the university (through the graduate dean) thereby ensuring that it does not contain anything that is at variance with the general university plans, policies or expectations.

C8. In addition to the material in C7, the president of each university is to make a statement concerning the university's plans for graduate work in the mathematical sciences. This statement may comment on the C7 statement and should at least explain the extent of the university commitment to the projections of faculty numbers and anticipated enrolment.

C9. The dates for submission of these various reports shall be fixed by ACAP.

D - Terms of Reference for Consultants and Advisors

D1. The consultants and advisors will meet with ACAP representatives for briefing. The consultants and advisors shall meet with the Discipline Group to discuss the terms of reference and practical arrangements for visits. If desired, consultants may at this stage suggest refinements or clarifications for inclusion in the terms of reference; if such suggestions are approved by ACAP, they will require ratification by OCGS and COU.

D2. The consultants and advisors shall consider the data and plans described in section C and may obtain other data and views from any relevant source, such as employers of holders of graduate degrees, professional and learned societies, the Science Council commission on mathematics. They shall acquaint themselves with the COU principles governing planning assessments and with some completed planning assessment reports.

D3. The consultants and advisors shall visit universities in accordance with a schedule established by the consultants and ACAP. The detailed agenda for a visit will need to be established well in advance of the visit. The visiting team shall include at least two of the three consultants and at least one advisor for each of the areas in which the university proposes to give graduate work. If doctoral work is involved in an area, both advisors shall visit. At each university the consultants will meet with the various appropriate officers (deans, librarians, etc.) and with the chairman of each department involved in the assessment. They will also meet with staff and students of at least some of the areas concerned. An advisor will spend most of his time with the staff and students of his area of expertise, but will also meet with the chairman and with senior officers if there are particular matters concerning his area on which he needs information from such sources.

D4. Apart from the initial meeting with the Discipline Group, the consultants may arrange other meetings with the Discipline Group, as they feel necessary or at the request of the Discipline Group, in either case after consulting ACAP.

D5. The consultants and advisors shall prepare reports as described in sections E and F.

E - Area Reports

E1. For each university, there shall be prepared an Area Report for each area in which that university offers or proposes to offer graduate work. These reports will be drafted by the two advisors in the area, even if only one visited, and are to be finalized in consultation with the consultants who visited the university.

E2. Each Area Report will deal with one university only and will cover the following:

(a) Fields - for each field, discuss faculty numbers, student numbers, courses given, course enrolments, quantity and quality of research output, number of master's and PhD degrees awarded, suitability of doctoral thesis topics, quality of doctoral theses

(b) Can the current staff deal with the number of students projected for five years? If not, what additions seem necessary? (Undergraduate load will need to be considered.)

(c) The location of the undergraduate training of the students

(d) Comment on the adequacy of research and study space (office space) for staff and students. Comment on other physical facilities, including computer adequacy and computer availability to the graduate student

(e) Discuss library resources on the basis of report supplied

(f) Examine and comment on admission standards and, if possible, on the academic quality of the graduate student body

(g) For doctoral programmes for each field indicate the quality of education offered the student, using the following categories:

(i) outstanding (e.g. comparable with the best in the world)

(ii) excellent (e.g. in the top four or five in Canada)

(iii) competent to good (e.g. there would be little hesitation in advising a good student to enter the programme)

(iv) questionable (e.g. either the quality is inadequate or further study is required to establish its adequacy)

The judgements should be justified by a discussion and should refer to the current state, but if any change (in either direction) can be confidently foreseen it should be reported.

E2. (h) List the fields of the area in which doctoral theses should at present be supervised with explanatory comment if desired (this is particularly important for programmes with fields in categories (iii) and (iv) but is requested for all programmes)

E3. Each Area Report shall be submitted to

(i) the university concerned

(ii) the consultants

(iii) ACAP

Area Reports are NOT to be published or further distributed except that, if COU feels that an Area Report is relevant to the final COU discussion of the ACAP report, the Area Report will be made available to COU, but not for publication.

E4. All Area Reports will be distributed simultaneously.

E5. Each university will be invited to comment as it sees fit on each of its Area Reports. The university comments will be submitted to ACAP and transmitted by ACAP to the consultants and advisors. The university comments will NOT be published or further distributed, except to COU on its request as with Area Reports.

F - Consultants' Report

F1. After the deadline for receipt of comments on Area Reports from the universities, the consultants shall draft a single Consultants' Report. It will be based on the material described in D2, the Area Reports, the comments thereon and of course their university visits. It is important that the reasoning behind the recommendations in the Consultants' Report be apparent, and to this end they should include information from the Area Reports in any manner which seems to them to be appropriate for their own report which will be a public document. They may also obtain assistance from their advisors on general considerations concerning the development of the four areas in the province or more widely.

F2. In their report, the consultants shall:

(a) Give a general discussion of the current state of graduate training in mathematical sciences in Ontario including at least the following topics:

general level of quality

suitability of graduate programmes as preparation for subsequent employment

any significant gaps in coverage of fields

any overemphasis on some field(s)

summary of material in items E2(a) (d) and (e) of Area Reports

adequacy of research funding for support of graduate programme

relationship to related disciplines

(b) Discuss changes in field emphasis or in content of applicability of mathematical graduate training which should be expected and/or encouraged in the next decade

(c) Discuss society's needs for holders of graduate degrees on a five to ten year basis and in this connection comment on the planned enrolments submitted by the universities. Discuss the likely number of well qualified applicants for admission, allowing for changing patterns of immigration, and compare with the universities' enrolment projections. (It is recognized that the consultants are not primarily experts on manpower projections and, while the above discussion is an essential part of the planning assessment, corrective recommendations will be made by COU only if there is a gross mismatch between the universities' enrolment projections on the one hand and the anticipated total of well qualified students or a reliable estimate of needs on the other.)

(d) Discuss the relationship between the size of programme (enrolment and field scope) and the quality of training it offers a student. Consider the role of postdoctoral fellows in this connection

(e) Discuss any other general matters important for the development of graduate work in the mathematical sciences in Ontario

(f) Make recommendations concerning the most significant points in the above discussions (or otherwise emphasize their importance)

(g) On the basis of detailed assessment, recommend the role to be played in the provincial pattern of graduate education in the mathematical sciences by every area proposed by a university. Some possible recommendations are: continuation in accordance with the official plan submitted by the university (C7 and C8), or a more restricted undertaking either in numbers of fields or students, or a larger or broader programme, or suspension of enrolment, or discontinuance of the programme, or continuation in some form if successful in an appraisal, or initiation of a new programme subject to appraisal, or joint programmes or cooperative ventures

In all cases, it is important that the rationale for recommendations be clear and the consultants should give their judgement of the standard of each subfield by university in the same manner as described for Area Reports in item E2(g).

(h) Discuss the realistic possibilities for cooperative activity involving a mathematical sciences department and another department or institute, either mathematical or not, either in the same university or another. Make recommendations as seem appropriate for specific cases.

F3. The consultants shall submit a draft report to ACAP to permit ACAP to ensure that it meets the terms of reference listed in F2. The Consultants' Report will then be submitted to ACAP.

G - ACAP and COU Reports

G1. ACAP will then prepare a draft ACAP Report.

G2. ACAP shall send its draft Report with the Consultants' Report as an appendix to the universities and to the Discipline Group for comment on both these reports. At this stage, or during the preparation of the ACAP draft Report, there could be meetings between ACAP representatives and the Discipline Group and/or some universities, if any party requested such a meeting. There could also be referral of questions to the consultants by ACAP and any material provided by the consultants shall be published by ACAP if it has been used for its Report.

G3. The comments of the Discipline Group on the Consultants' Report will be published as will those of any university so requesting, but the comments on the ACAP draft Report will not be published.

G4. After receiving the comments, ACAP will prepare the final ACAP Report and submit it to COU with copies to OCGS, CDAS and the Discipline Group.

G5. COU will not take final action on the COU Report until it has allowed at least one month for the receipt of any written comment on the ACAP Report from universities, OCGS, CDAS or the Discipline Group. COU will decide what comments it will publish. As a minimum, COU will publish the COU Report and the ACAP Report including the Consultants' Report and those comments on the Consultants' Report that are to be published.

Appendix I

Mathematical Sciences Discipline Group

1. Establishment of Group

   a. On November 15, 1974, OCGS authorized the establishment of a Mathematical Sciences Discipline Group with the following membership: two from each university intending to carry on graduate work, and containing at least three persons working in each of the four areas: pure mathematics, applied mathematics, statistics, computing. If the persons nominated by the universities should not include three from each area, ACAP is to coopt additional professors to make up the necessary number. When there are matters for which it is desirable to have input from every university concerned with one of the four areas, the Discipline Group will be expected to establish ad hoc subcommittees.

   b. Changes of a university's representative are to be notified by the executive head.

   c. The Group shall select its own chairman.

2. Meetings

   a. The Discipline Group may meet at the call of its chairman or in accord with its own arrangements.

   b. The Discipline Group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

   a. COU has instructed ACAP to conduct a planning assessment in the Mathematical Sciences and the Discipline Group will assist and advise ACAP and generally facilitate the assessment.

   b. In the future, the Group is to keep under review the plans for graduate work in the Mathematical Sciences in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis. For this purpose ACAP will assist the group in obtaining information and data, as mutually agreed.

   c. The Group may make recommendations to ACAP in connection with graduate work in the Mathematical Sciences when it considers it appropriate.

APPENDIX B

RESPONSE OF THE DISCIPLINE GROUP

RESPONSE OF THE MATHEMATICAL SCIENCES DISCIPLINE GROUP TO THE CONSULTANTS' REPORT

The Discipline Group met on August 25, 1976 in the offices of the COU to discuss the report. There was a general feeling of satisfaction with its overall views and recommendations - we felt that the advisors and consultants had done a commendable job considering the enormity and complexity of the task. We sincerely hope that this report and the decisions made by the Discipline Group itself will lead to an improvement in the already high quality of the Mathematical Sciences in Ontario noted by the consultants.

Most of our discussion centered around a small number of topics which were thought to be of particular importance and which are dealt with separately below.

OPTIMAL NUMBER OF GRADUATE STUDENTS

The Discipline Group was very disturbed by the conclusion that a figure of around 40 Ph.D.'s per year would be realistic for the period 1975-1980 (see page A-23) and by the statement that the number of Ph.D.'s in each of the four areas should be roughly equal. Certainly a figure of around 10 Ph.D.'s per year in Pure Mathematics seems to us a reasonable number. In Statistics the figure of 10 is possibly low, if not now then very likely in a few years. Several departments in Ontario have recently had considerable difficulty hiring Statisticians, and in addition there may be an increased demand in non-academic institutions in the near future. In Applied Mathematics the possibilities of non-academic employment could create a need for more Ph.D.'s in the early 1980's, which would call for an increase in the number of students in the next two or three years. The difficulty of making reasonable estimates for the number of Ph.D.'s required in Applied Mathematics is aggravated by the presence of other university departments which provide similar graduate instruction (for example, Engineering and Management Sciences).

In the case of Computer Science, the figure of 10 is far too low even at the present time and a figure of 15 to 20 would be much more realistic. For example, the U.S. produces somewhere in the neighbourhood of 300 Ph.D.'s per annum in Computer Science, so on a per capita basis Canada might be expected to produce 30. In view of the small number of Computer Science Ph.D. programs in Canada, Ontario might well be expected to produce about 20 of these. There is a continuing demand in both the academic and non-academic worlds for graduates, indicated, for example, by the paucity of post-doctoral students available.

We should also like to point out that recent statistics given by ACAP indicate that the actual number of Ph.D.'s produced annually in each of the four areas is tending towards the numbers which we suggest above. They appear to demonstrate that the graduation of Ph.D.'s in Ontario during the next few years will be as close as one could reasonably expect to the employment opportunities available. It should also be pointed out, of course, that the recent change in graduate financing by the province of Ontario will tend to reduce graduate population figures.

Our group feels that continuous monitoring of the graduate student population in the Mathematical Sciences in Ontario (Recommendation 1 i))is a good idea and that this function can be carried out adequately by the Discipline Group.

LENGTH OF PH.D. STUDY

In the second paragraph on page A-15, the consultants state that the time required for the doctoral degree should not exceed three or four years of full time study beyond the baccalaureate under normal circumstances. We disagree with this view and feel that a more appropriate figure is four to five years, especially in view of Recommendation 43 which suggests that more comprehensive requirements for students both in applied subjects and in Pure Mathematics are desirable, and also in view of the consultants' stress (with which we agree) that the emphasis on graduate education in Ontario should be on quality rather than on quantity.

SIZE OF GRADUATE PROGRAMS, INTER-UNIVERSITY COLLABORATION AND GRADUATE SUPERVISION

In chapter III, section 3., the consultants state that "most research students should work in centres where there are an appreciable number, five or more research students in their area, but that other departments with the facilities to provide programmes of the necessary quality should not be barred from doing so". The Discipline Group is in agreement with the notion that it is generally advantageous to have several students in each area but would like to stress that, more generally, the level of activity in an area is the essential factor. One manifestation of such activity is certainly the presence of graduate students, but there are obviously others as well: the numbers of faculty and post-doctoral students (and their publications), frequency of seminars, etc.

In the same section, it is also stated that "it is not economically viable to mount a thorough programme of course work within an area without a reasonable number of students". This seems to us perfectly clear and we feel that it is unlikely that a university would allow a graduate program to remain in existence if the number of students dwindles to such a point. This is, of course, also a matter which would be, and probably should be, monitored by the proposed inter-university committee on the Mathematical Sciences.

The consultants also allude to the fact that the stimulus for research in mathematics need not come from an active graduate student program but can come from interaction between faculty members and post-doctoral students. We are in agreement with this point of view and we feel, furthermore, that the universities should do more to promote such collaboration, not only within each institution but with mathematicians in neighbouring institutions. To this end we suggest that the universities provide some financial assistance to augment the use of NRC operating grants for such collaboration, by using some of the funds made available from cuts in the graduate student population. In particular because of the isolation of Lakehead and Laurentian Universities, the Discipline Group recommends that provincial funds be provided for additional travel by faculty, students and post-doctoral students from these two institutions to encourage their collaboration with others.

A matter closely related to this is the consultants' suggestion that Ph.D. students be allowed to choose a supervisor at a different institution, and that in any case all Ph.D. supervisory committees have one member from another institution. The Discipline Group enthusiastically supports this proposal with the proviso that such an arrangement be strongly encouraged but not mandatory, for the obvious reason that there will certainly be circumstances under which it would be highly impractical. We feel that the appointment of external advisors would not only be of benefit to students but would foster collaboration among the faculty in the province, and we recommend that each university provide the necessary travel funds to enable the student and the external advisor to meet regularly. We believe, in fact, that many institutions already have such funds available.

MASTER'S DEGREE

There was some feeling in the Discipline Group that the consultants did not deal as adequately as they might have with the master's degree. The Discipline Group was unanimous in recommending that any university offering a master's degree should be allowed to grant the degree either by course work and thesis or by course work alone. The Discipline Group also heartily supports Recommendation 41 i) that part-time study at the master's level be encouraged.

UNIVERSITY RECOMMENDATIONS

The Discipline Group felt that responses to the recommendations concerning individual universities are best made by the institutions themselves. There was, however, some discussion on several of the recommendations which we should like to report.

First of all, in the introduction to the area reports on Computer Science (p.A-63), the consultants "see some danger of an isolation of Computer Science from the other areas in the Mathematical Sciences" and they state that "the links between computer science and relevant areas of pure mathematics, especially algebra, and between computer science and applied mathematics, numerical analysis, and statistics, all need strengthening". We feel that these statements might be interpreted as implying that Computer Science should weaken its ties with other university disciplines such as Science, Engineering and Social Sciences. Such a step would clearly be retrogressive and to prevent such an interpretation, we would have used the phrase "to be maintained" in lieu of "strengthening".

On another point, the consultants noted, in the area reports of several institutions, that Ph.D. theses were less than satisfactory. Several members of the Discipline Group felt that these statements were erroneous since many of these theses were published in journals of good repute,and, more importantly, the amount of time available to the advisors and consultants to form such judgments was inadequate. Others felt that certain conclusions regarding the quality of theses were possible and that in any case the comments of the consultants thereto should be accepted as their honest opinions.

SUMMARY

1. The Discipline Group agrees that the proposed number (10 per annum) of Ph.D.'s in Pure Mathematics is reasonable. In the case of Applied Mathematics and Statistics, the figure of 10 is about right at the

moment, but will likely be too low 5 or 6 years from now. In Computer Science a figure of 15 or 20 is more realistic.

2. The Discipline Group considers 4 to 5 years to be the desirable time from the B.Sc. to the Ph.D., not 3 to 4 years as suggested by the consultants.
3. The Discipline Group supports the view that research stimulus should be based increasingly on collaboration among faculty and post-doctoral students rather than on a graduate program, and suggests that universities encourage such activity. In particular we recommend that special provincial funds be made available to mathematicians at Lakehead and Laurentian Universities to enable them to participate fully in the mathematical activity of the province. We also support the idea of external Ph.D. advisors when practicable, and suggest that universities provide financial support for such arrangements.
4. The Discipline Group supports the encouragement of part-time master's study, and recommends also that master's degrees be obtainable by course work and thesis, or by course work alone.
5. With regard to the Area Reports in Chapter II, the Discipline Group
   - (i) would have preferred a suggestion by the consultants that the links between Computer Science and the other areas of the Mathematical Sciences be "maintained" rather than "strengthened", in order to avoid the possible inference that ties with disciplines outside of Mathematics should be weakened.
   - (ii) discussed the validity of the consultants' (and advisors') conclusions about the quality of Ph.D. theses in view of the limited opportunity to examine them. There was no clear consensus on the question.

APPENDIX C

UNIVERSITY COMMENTS

Comments appear from Carleton, Guelph, Lakehead, McMaster, Toronto, Waterloo and Western Ontario.

October, 1976

C-1

CARLETON UNIVERSITY

RESPONSE TO CONSULTANTS' REPORT

MATHEMATICAL SCIENCES

1) General Comments:

Considering the limitations under which the consultants and advisers worked, and which are inherent in such a wide-ranging study conducted in a relatively limited time period, we are impressed by the thoughtful and penetrating document they have produced. Globally, we believe that they have accurately assessed the current state of affairs in the mathematical sciences in Ontario and that their recommendations are sound and in the right direction.

2) Response to Specific Recommendations:

(a) Cooperation with the University of Ottawa
(Recommendations 15.i; 22.(iv), 32.iii)

Generally, we are working to improve collaboration with the University of Ottawa in all areas of the mathematical sciences. For example, we have instituted periodic meetings of the chairmen of the two departments to co-ordinate the schedling of graduate courses, to arrange for other joint activities and to keep each other informed about the academic plans of the respective departments. In Probability and Statistics we have proposed the institution of periodic full day joint workshop sessions for faculty and graduate students.

It is possible to arrange for faculty members of neighbouring universities to be involved with the supervision of Ph.D. students in our department when it is academically appropriate and provided that the other institution involved also gives its approval.

In response to 32.iii regarding the development of a comprehensive joint program of academic work in computer science for the Ottawa area, a committee has been formed which includes representatives of the Departments of Mathematics and Systems Engineering at Carleton University and the Department of Mathematics and Computer Science at the University of Ottawa with the responsibility of drawing up long-range plans.

(b) The M.Sc. Program in Information and Systems Science (Recommendations 22.iii, 32.i, 32.ii):

We are gratified that the consultants have recommended the implementation of the M.Sc. program in information and systems science. The question of the role of probability and statistics in this program has been referred to the joint committee for an internal review in the light of the consultants' comments.

The M.Sc. program at Carleton which is the joint responsibility of the Departments of Mathematics and Systems Engineering has already attained a viable size, and it appears to be a program that fills a demonstrated academic need at this University. Since the comparable program at the University of Ottawa involves five departments, such a joint program would involve the formidable organizational difficulties of co-ordinating a program involving two universities and seven departments. However, the Deans of Graduate Studies and Research of the two universities and a representative of the inter-university committee are currently investigating the possibility that some of the activities and courses of these two programs could be mutually useful.

(c) The Cooperative M.Sc. Program in Statistics (Recommendation 22.ii):

We are in complete agreement with the consultants' recommendation that this program be strongly encouraged since it has been an important step in our development of an M.Sc. program which provides for a sound and well-rounded training for a career in applied probability and statistics.

(d) The Doctoral Programs in Pure and Applied Mathematics and Statistics (Recommendation 4.ii, 15.ii, 22.i)

The report recommends that these three doctoral programs continue with more precise definition of the fields offered in the applied area. Although the latter point is under continuing review, a preliminary recommendation has been made by the department to specify the applied areas as follows:

(i) Applied Analysis and Dynamical Systems

(ii) Theory of Computation and Optimization

The first area has been established for a number of years and represents the natural continuation of these activities. The second area, the theory of computation and optimization, was selected four years ago by the department in its internal planning for graduate studies as one which should be given special priority and was singled out for encouragement in the A.C.A.P. consultants' report on Applied Mathematics. Since that time the foundation for this area, including the creation of basic courses, has been established and we are considering the completion of this development as soon as adjustments in staffing make this possible.

UNIVERSITY OF GUELPH
COMMENTS ON CONSULTANTS' REPORT
MATHEMATICAL SCIENCES ASSESSMENT

In expressing our general satisfaction with the report of the consultants we wish also to endorse the additional participation of advisors. This device for conducting the assessment of a complex discipline may well serve as a useful precedent for future assessments of comparable breadth.

In their first chapter the consultants have given their opinion on a number of points. We are particularly pleased to note those pertaining to faculty research, to the duration of a normal master's program, to critical size, and to university cooperation. We observe that Figure V on page A-20 does not illustrate what the words in the first line of Page A-19 lead the reader to expect. In that line, replacement of the words "graduate students" by "doctoral graduates" would remove the discrepancy. The consultants are to be commended for their careful analysis of employment opportunities.

In chapter II, the basic observations presented on pages A-29 and A-30 relate chiefly to doctoral programs, but the suggested emphasis on quality and relevance is also appropriate to master's programs; we share the implied concern of the consultants.

The statements concerning the University of Guelph seem to us to be both fair and unexceptionable. The suggestion for pure mathematics (pages A-39, 40) is a useful one, as is that for applied mathematics (pages A-50, 51).

We are gratified by recommendation 28 (page A-61) regarding our program in statistics, where we take particular note of the suggested cooperation with the University of Waterloo. The matter of faculty appointments, while no easier for us than for our sister universities, will not be lost sight of as appointment opportunities occur. In passing,we note with interest that the consultants have suggested a nominal distribution amongst the universities for ten Ph.D. graduates per annum in pure mathematics; but they have not done so for the ten Ph.D.'s in either applied mathematics and statistics (whether theoretical or applied). A suggested distribution in the latter area would have been helpful to Guelph in contemplating the possibility of a future development in applied statistics at that level.

The statement (pages A-69, 70) concerning our work in computer science is helpful. In this, as in the other areas, we are conscious of our location in the lee, if not the shadow, of Waterloo. We would welcome the opportunity of cooperation in the supervision of graduate students with our academic neighbours.

Finally, with regard to Chapter III, we endorse the intent of recommendation 38 (pages A-73, 74) in respect of inter-university arrangements, and would be prepared to participate where possible. Recommendation 41 (page A-77) regarding part-time students reinforces one aspect of the University's Aims and Objectives as published several years ago. And as for Recommendation 45 (page A-82) we observe that Guelph has for some time been involved in the coordination of library services.

The report, in brief, is a good one.

*****

August 12, 1976

Comments on "Planning Assessment of the Mathematical Sciences in Ontario", by Birkhoff, Cox and Morrish

The document referred to is the final report of the ACAP consultants. It differs little in essential respects regarding Lakehead University, from the preliminary document which reached us in December 1975. We feel that our comments forwarded on December 10, 1975, are still applicable, and wish to do no more at this time than summarize the major points discussed in the December 10, 1975 document.

1. We feel that the advisers and consultants have given Lakehead University a strong endorsation in the area of pure mathematics and we are encouraged to continue and strengthen our efforts in this program.

2. We believe that, while the ACAP advisers were careful to restrict their comments to the area of pure mathematics, we are justified in reading into these comments approval of our entire program, and plan to proceed on this basis.

3. With respect to the critical area of enrolment, we note that while the consultants conclude that programs can succeed with as few as five students, their comments on our low enrolment, and lack of "Canadian content", are fair. However, the described situation is not one that we can easily remedy with the existing area restrictions on our M.Sc. program, and it is vital to us that our present successful program be broadened into other applicable areas of mathematical sciences.

McMASTER UNIVERSITY
Dean of Graduate Studies
1280 Main Street West, Hamilton, Ontario, L8S 4K1
Telephone: 525-9140

September 28, 1976

Dr. H. H. Yates,
Executive Vice-Chairman, OCGS,
Council of Ontario Universities,
130 St. George Street, Suite 8039,
Toronto, Ontario.

Dear Dr. Yates:

In commenting on the reports of the Mathematical Sciences assessment we confine our attention to the consultants' report. Our comments on that report however, bear directly on some of the statements made on page 19 of the ACAP draft Report, namely those concerning the quality of our mathematics theses and the Statistics faculty, as well as Recommendation C12.

Pure Mathematics (p. A-37).

We feel that the consultants' comments on our Pure Mathematics programme generally are fair and accurate. There are only two points on which we take issue with the consultants.

1) As we noted in our response to the advisors' report on Pure Mathematics we are very unhappy with the statement that the overall quality of the majority of the doctoral theses examined was "acceptable" and that there was none that could be described as "really outstanding". We contend that there have been several theses written by our students which, by most peoples' standards, are considerably better than "acceptable". We would rate them as outstanding. We have on file reports from external examiners, who are internationally known mathematicians, that describe these particular theses as "excellent". In addition, we note that more than 20 of our Ph.D. theses have resulted in publications in such journals as the J. f. d. Reine u. Angew. Math., Trans. A.M.S., Can. J. Math., Pac. J. Math., Math. Zeit., Math. Jap., J. Algebra, Abh. Math. Sem. Hamburg.

2) The statement in the fourth paragraph that "the majority of the doctoral theses ... examined were, understandably, in the area of Algebra", may create the impression that the majority of our Ph.D. theses are in Algebra. It was pointed out in our response to the advisors' report that this is incorrect and that the 46 theses completed to date have been distributed as follows: Algebra 12, Analysis 17, Geometry & Topology 11 and Graphs & Combinatorics 6.

The consultants suggested that "unless some positive steps are taken,... it will be difficult to maintain a lively and vital programme in Pure Analysis at McMaster". In this regard it is important to note that the University recently has appointed two new faculty members in the area of Analysis. One of them, Dr. C. Bennett, has been appointed in the Department of Mathematics and the other, Dr. M. Ismail, has been appointed in the Department of Applied Mathematics. These appointments strengthen considerably our work in Analysis, work which we believe is already well in line with current interests and applications as called for by the consultants.

Statistics (p. A-59).

We are anxious to clarify the situation in regard to our graduate programme offerings in this area. As we noted on pages 8-9 of our Five Year Plan, which was part of the material submitted earlier in connection with this assessment, we do not offer doctoral work in Statistics. We concede that our Graduate School calendar is somewhat misleading on this point and we intend to change the appropriate sections of that document. We do offer doctoral work in Probability Theory but we regard this as Pure Mathematics and not Statistics.

The statement concerning the "heterogeneous" quality of faculty in the Statistics area prompts a comment. We do not object to the overall judgement but we would note that the consultants recognized that we do have some very strong faculty members in this area including "a statistician of internationally broad repute". They are however, located in several departments. We are engaged in a thorough reorganization of our Statistics graduate work in order to unify our offerings and coordinate our strengths and we shall be happy to put the revised programme forward for appraisal.

Computer Science (p. A-68).

Our Computer Science group has re-thought and re-structured the graduate programme so as to emphasize more distinctly its interdisciplinary character. When the opportunity arises, the University will give careful consideration to the recommendation that another faculty member be added to strengthen the core subjects in Computer Science.

We request that the above comments on the consultants' report be published.

Very sincerely yours,

Leslie J King

Leslie J. King,
Dean.

LJK/del

C-9

UNIVERSITY OF TORONTO
School of Graduate Studies

OFFICE OF THE DEAN

Toronto, Canada M5S 1A1

September 8th, 1976.

Dr. H. H. Yates,
Executive Vice-Chairman,
Ontario Council on Graduate Studies,
130 St. George Street,
Suite 8039,
Toronto, Ontario,
M5S 2T4.

Dear Dr. Yates,

I am writing to forward the University of Toronto's comments on the consultants' report in the Mathematical Sciences which we would wish to have published.

The University wishes to express its definite satisfaction with the consultants' report, which emphasises the need for quality and relevance in doctoral research, and which clearly makes the point (p. A-14) that, while a teaching staff able and active in research is essential to strong graduate programmes, 'the converse does not follow'. These are views for which this University has long been an advocate. We are naturally gratified by the many positive comments made about our graduate programmes in the mathematical sciences and by the recommendations that they all continue. We especially welcome the very high opinion expressed by the consultants of this University's Department of Computer Science.

There is no doubt that the physical separation of the Department of Mathematics in many buildings, some of marginally adequate quality, has severely hampered communication within the Department. Some steps have recently been taken, and more are being planned, to improve the quality of the Department's space, but, in our current circumstances, complete centralization (particularly by new building) appears beyond our reach. It should be noted that Mathematics is by no means unique in this respect; many of our departments are physically split between several locations. In an 'old' university, lack of adequate funding for renovation and renewal of outdated space has caused, and will increasingly continue to cause, academic difficulties of the kind noted by the consultants.

We intend to give very careful consideration to the recommendations of the consultants regarding the review of our programmes in pure and applied mathematics, and the need for organizational change in statistics. In pure mathematics, the consultants have outlined four areas for study; it would be helpful if we might have some indication of the precise nature of their concerns, which might best be obtained (if ACAP has no objection) by direct discussion between the consultants and the chairman of the Department.

In applied mathematics, we welcome, and propose to implement, the suggestion that an interdisciplinary review committee be established. We propose, however, to broaden its scope. As the consultants have noted, much applied mathematics is done outside mathematics departments. We would therefore include applied mathematicians from social, physical, and life science departments (including engineering) on such a committee. Close linkages between the four mathematical areas are clearly necessary: at Toronto there are other linkages (such as that between Computer Science and Electrical Engineering) which are equally important, and which have contributed significantly to the strength of our programmes.

In statistics, five additional cross-appointments have already been made to strengthen the Institute of Applied Statistics, and one new appointment has been made in the Department of Mathematics. We expect a final organizational solution to be evolutionary rather than revolutionary in nature. While evolution towards departmental status for the Institute is acceptable in principle, the new appointments needed can be made only slowly (if at all) in the current financial situation.

The suggestions made by the consultants regarding cooperation between Toronto and York in the mathematical sciences are acceptable in principle, and are already being followed up.

There are a very few minor points of fact which should be clarified. On page A-13, it is indicated that artificial intelligence, computer graphics, solid mechanics, and control theory are not covered adequately in Ontario. The first two topics are, as indicated on page A-63, covered in our Department of Computer Science. From previous ACAP assessments, there appears to be considerable mathematical strength in solid mechanics at Waterloo, but located in Civil Engineering rather than Mathematics. At Toronto, there is very considerable strength in control theory, but located primarily in Electrical Engineering, and only partially in Mathematics. These two examples illustrate the difficulties of assessing applied mathematics only on the basis of work done in Mathematics departments; the consultants recognize this problem, but it is worth re-emphasizing here.

Finally, on page A-64, encouraging the University of Toronto to cooperate with Scarborough College is unnecessary: both Scarborough and Erindale Colleges are integral parts of the University of Toronto, and their staffs participate fully in the graduate activities of the Departments in which they also hold appointments.

Yours sincerely,

James M. Ham

James M. Ham,
Dean.

CC: Dr. J. R. Evans,
Dr. D. A. Chant,
Dr. G. E. Connell,
Professor M. Israel,
Dean R. A. Greene,
Dean H. W. Smith,
Dean R. W. Missen,
Professor J.N.P. Hume,
Professor J.C. Ogilvie,
Professor F.V. Atkinson,
Professor S.H. Smith.

Response of the University of Waterloo to the Report of the Mathematical Sciences Consultants to the Advisory Committee on Academic Planning

submitted to ACAP, June 25, 1976

General Comments:

The University of Waterloo finds itself in general agreement with the report of the consultants in the mathematical sciences. We believe that the consultants and the area advisors are to be congratulated for the manner in which they have carried out a difficult and complex assessment. We are particularly pleased to note the recognition by the consultants of the generally high quality of the graduate programmes in the mathematical sciences offered at the University of Waterloo. Waterloo is unique in Canada in the emphasis it places on the mathematical sciences both at the graduate and undergraduate levels. The quality of our undergraduate programmes in mathematics is attested to by the success of our baccalaureate graduates in competitions for national scholarships such as those offered by the National Research Council and in the success of University of Waterloo teams in the Putnam competition over the last several years. In this prestigious competition, to which the consultants refer, Waterloo has stood first in 1974, second in 1968 and received honourable mention for 6th and 7th place in 1975 and 1973 respectively. The University will continue its efforts to maintain high quality graduate and undergraduate programmes in the Mathematical Sciences.

Specific Comments:

While we find the consultants' report generally acceptable we do wish to make a few specific comments. In the section on pure mathematics the consultants recommend (recommendation 3(i)) that there should be a uniform qualifying examination for intending doctoral candidates in pure mathematics including those in the Department of Combinatorics and Optimization. We can report that the Departments of Pure Mathematics and Combinatorics and Optimization have already taken steps to implement this recommendation and have established a joint committee to generally coordinate the programmes. The suggested production of about 3 Ph.D.'s per year in pure mathematics is reasonably consistent with our present enrollment. The two departments will continue to maintain high standards for the admission of students to the graduate programmes in pure mathematics.

In the section devoted to applied mathematics there is a disturbing reference to the effect that Waterloo has a "definite intention to relax admission requirements in an effort to double enrollment". We can state categorically that the Department of Applied Mathematics has no such intention. The Department does plan to expand its enrollment slowly over the next few years but we believe that this expansion will be justified by the job market for applied mathematicians particularly in positions outside of academic circles and that it can be met without lowering admission standards. If these expectations are not fulfilled the expansion will not occur.

In the section on statistics the consultants recommend that arrangements for consulting work with other departments be strengthened. The University has already established an intra-university consulting service which is located within the Department of Statistics. This service is staffed by faculty members and students. The teaching loads of faculty members involved are reduced where there is a substantial amount of time devoted to service. The consultants also recommend increased collaboration with other universities, particularly Guelph. The University of Waterloo is already involved in joint discussions with the University of Guelph to consider the possibility of greater involvement of Guelph faculty with Waterloo graduate students and the establishment of joint seminars. The possibility of expanding this activity to include other nearby universities is also being investigated.

In their general comments on part time students the consultants make the observation that there may be more scope for specialized master's work and specifically mentioned the field of actuarial science. The actuarial group in the Department of Statistics at Waterloo has been offering graduate level courses in actuarial science for several years both on campus and in Toronto. There is a strong demand for these courses from individuals preparing for the higher examinations of the Society of Actuaries. The University does not offer a specialized master's degree in actuarial science but students can combine actuarial science courses with courses in statistics and computer science for an unspecialized master's programme. The Department of Statistics is also planning to offer an intensive course in statistics for workers in industry on an experimental basis during the summer of 1977.

In the section on computer science the consultants express concern for the future of scientific computing. The University of Waterloo has always had considerable strength in the area of scientific computing and we intend to maintain that strength. Master's enrollment in computer science has reached the level planned and will be maintained at that level. We do not envisage any significant expansion in masters enrollment. The Department of Computer Science will continue to maintain high standards for admission to its graduate programmes.

RESPONSE OF THE UNIVERSITY OF WESTERN ONTARIO TO THE CONSULTANTS' REPORT ON THE MATHEMATICAL SCIENCES PLANNING ASSESSMENT

The following comments are provided on the Consultants' report in the Mathematical Sciences as a consequence of discussions of a Committee appointed to examine this report.

Pure Mathematics

1. We note with satisfaction the comments of the Consultants concerning the high proportion of Canadian graduate students in the programs. The visa student component of all graduate programs at Western is regulated in such a way that it does not exceed 20%. This level has been maintained in Mathematics.

2. The Consultants' comment upon the specialized nature of the doctoral program noting that doctoral studies have centred around summability theory and semigroup theory and automata. Two senior appointments with established reputations have since been made in the area of algebraic topology.

3. The Departments note a request for reappraisal of the doctoral programs in pure mathematics and statistics. We accept these recommendations but believe the remarkably short period provided to consolidate new areas of strength may present difficulties.

Applied Mathematics

1. We note with pleasure the recognition given to Theoretical Physics in the present Mathematical Sciences assessment. Based upon the research record of the theoretical physicists in the Applied Mathematics Department, we believe the present evaluation much more closely describes the prevailing state than did the comments in the Physics report (Report No. 14).

2. The organizational rearrangements recommended in Report No. 14 (page 4, No. 10) and commented upon by the Mathematics Consultants have been addressed by the University and a revised program has been filed with the OCGS Appraisal Committee.

Statistics

1. Unification of the organizational arrangements for statistics within the Faculty of Science is now being implemented with a view in the near future to increasing collaboration with other parts of the University. Final arrangements should be completed in the next few months. A statistical consulting service has been in operation for three years. Plans are in hand for the expansion of this service to statistical laboratory which will serve as a focal point for the statistical activities of all statisticians and users of statistics in the University.

2. A regular graduate course in probability theory has been re-established and will be offered in 1976.

Computer Science

1. While Western is disappointed with the recommendation concerning a Doctoral program, it has concluded that a collaborative program with another university is not immediately feasible.

2. The department is nonetheless pleased that the success of its M.Sc. program has been recognized. Steps have already been taken to raise the admission requirements (which were not previously below the Provincial standards) for the Master's program in Computer Science and there has been a corresponding decrease in enrolment.

October 1976

APPENDIX D

PROCEDURE OF PLANNING ASSESSMENT
AND
TERMS OF REFERENCE

Procedure for Mathematical Sciences Planning Assessment

Approved by COU - January 10, 1975.

A - Interpretation

This document uses several words in specialized senses. These meanings follow.

Acronyms:	COU - Council of Ontario Universities OCGS - Ontario Council on Graduate Studies, an affiliate of COU. ACAP - Advisory Committee on Academic Planning, a committee of OCGS, established by By-Law No. 3 of OCGS. CDAS - Council of Deans of Arts and Science, an affiliate of COU
Advisor:	A mathematics expert whose functions are explained below; there are two advisors for each area.
Appraisal:	A procedure leading to a decision as to whether or not the quality of a programme is or will be adequate; the universities have agreed not to begin new programmes without first obtaining an appraisal and not to add new fields to existing programmes without referral to the Appraisals Committee to decide if an appraisal is required.
Appraisals Committee:	A committee of OCGS, established by By-Law No. 2 of OCGS.
Area:	One of the four divisions of the mathematical sciences used in this planning assessment, viz. pure mathematics, applied mathematics, statistics, computing science.
Consultant :	One of three persons who are consultants to ACAP and whose functions are described more fully below; they are aided by "advisors".
Discipline Group:	Refers to the Mathematical Sciences Discipline Group, constituted as authorized by OCGS on 15 November, 1974. See Appendix I.
Graduate Programme:	The word "programme" is used to signify all aspects of the graduate undertaking of a department (or institute, etc.), including the actual and planned faculty strength, extent and limitations of areas of research specialization, research facilities, and curriculum.

Planning Assessment:	A formal review of current and projected graduate programmes within a discipline or a group of disciplines, in this case within the mathematical sciences and embracing the four "areas" listed above.
Reports:	Four types of reports are referred to and described in this procedure: a. An Area Report, written by area advisor and submitted to the university concerned, the consultants, and ACAP. b. The Consultants' Report, written by the consultants and submitted to ACAP, and dealt with as described in Section G2. c. The ACAP Report, written by ACAP and submitted to COU. A draft form is first provided for comment to universities and to the Discipline Group. d. The COU Report, containing COU's recommendations to the Ontario Council on University Affairs and to the universities.
Field:	Each of the four areas is further subdivided into fields.
University Plan:	Denotes the official statements made by a university in accordance with paragraphs C7 and C8 below.

B - Choice of Consultants and Advisors

B1. There shall be three consultants, two of whom shall be mathematicians of international standing with breadth of outlook on the mathematical sciences and with suitable administrative or consulting experience. The third consultant shall be a person of wide academic experience in Canada but not in mathematics. No consultant shall be on the permanent staff of an Ontario university.

B2. ACAP shall call the Discipline Group together to discuss the choice of consultants and to nominate a list of about ten potential consultants. If it seems desirable, ACAP may also propose names, but they shall be approved by the Discipline Group.

B3. From the resulting list, ACAP shall select its consultants.

B4. There shall be eight advisors, two for each area. Each advisor shall be an acknowledged expert in the relevant area and at least one advisor in each area shall have extensive experience with graduate work. No advisor shall be on the staff of an Ontario university.

B5. The Discipline Group shall establish four ad hoc area subcommittees for the purpose of proposing names of potential advisors for each of the four areas. Each subcommittee shall consist of persons who work in the area in question and there shall be one member from each university that proposes to offer graduate work in the area; in so far as possible the members of the subcommittees shall be members of the Discipline Group. Each subcommittee shall meet with an ACAP representative to discuss the choice of advisors and to prepare a list of at least eight nominations. These nominations shall be submitted to ACAP through the Discipline Group which may comment on the choices.

B6. ACAP shall select the advisors from these lists, and may obtain help from the consultants in doing so.

C - Collection of Data and of University Plans

C1. ACAP staff will prepare draft forms and instructions for collection of data as described in paragraph C6. The Discipline Group will examine and comment on these forms and instructions, in particular on the choice of fields.

C2. After the forms have been completed by the universities, the Discipline Group will examine the data supplied, and indicate any inadequacies or inconsistency of reporting standards.

C3. The Discipline Group will consider and discuss also the university plans submitted. The Group may make suggestions to an individual university or to ACAP as a result of these discussions.

C4. If the discussions of C3 were to lead a university to modify its plans, it would so notify ACAP.

C5. If a university changes its plans at any time before the completion of the planning assessment, it shall notify ACAP of the changes. Consultants are instructed to disregard any material provided to them which is at variance with the statements provided by the university through ACAP.

C6. Each university is to supply to ACAP (in the form decided following procedure C1) the following information:

(a) the areas and fields currently offered for master's and doctoral work

(b) for each area and field current lists of faculty members, numbers of faculty members, enrolments, degrees granted and drop-outs in previous years

(c) curricula vitarum of all faculty members now engaged in graduate instruction or soon expected to be

(d) historical data on graduate students covering,

- (i) enrolment
- (ii) immigration status and country of first degree
- (iii) financial support
- (iv) drop-out number
- (v) degrees granted
- (vi) post-graduation employment of PhDs
- (vii) employment of ABDs
- (viii) list of doctoral thesis topics

(e) data on the undergraduate base, in particular enrolment in work leading to graduate study

(f) data and statements on resources of space and laboratory and computing facilities

(g) data and statements on library resources, in a form to be worked out in conjunction with the Office of Library Coordination

(h) support from related departments

(i) inter-university arrangements for graduate study in mathematical sciences

C7. Each university is to supply to ACAP a statement of its plans for the future of graduate work in the mathematical sciences, in as much detail as possible, under each of the headings (a), (b), (f), (g), (h) and (i) in C6, including explicitly the planned numbers of faculty and graduate students in each area for the next five years. The plans shall treat the years 1975-1980 in detail and should look ahead to about 1985 in outline. The plans should be accompanied by arguments supporting their appropriateness and should consider the projected enrolments in terms of the sources and motivations of potential students. Since the consultants are to deal with changes in field emphasis and in methods and content of mathematical graduate education, any plans bearing on these topics should be presented. It is expected that the plans presented in response to this procedure (C7) will be largely generated at the departmental level, and may contain components on which the university cannot comment at this time; the statement shall however be submitted by the university (through the graduate dean) thereby ensuring that it does not contain anything that is at variance with the general university plans, policies or expectations.

C8. In addition to the material in C7, the president of each university is to make a statement concerning the university's plans for graduate work in the mathematical sciences. This statement may comment on the C7 statement and should at least explain the extent of the university's commitment to the projections of faculty numbers and anticipated enrolment.

C9. The dates for submission of these various reports shall be fixed by ACAP.

D - Terms of Reference for Consultants and Advisors

D1. The consultants and advisors will meet with ACAP representatives for briefing. The consultants and advisors shall meet with the Discipline Group to discuss the terms of reference and practical arrangements for visits. If desired, consultants may at this stage suggest refinements or clarifications for inclusion in the terms of reference; if such suggestions are approved by ACAP, they will require ratification by OCGS and COU.

D2. The consultants and advisors shall consider the data and plans described in section C and may obtain other data and views from any relevant source, such as employers of holders of graduate degrees, professional and learned societies, the Science Council commission on mathematics. They shall acquaint themselves with the COU principles governing planning assessments and with some completed planning assessment reports.

D3. The consultants and advisors shall visit universities in accordance with a schedule established by the consultants and ACAP. The detailed agenda for a visit will need to be established well in advance of the visit. The visiting team shall include at least two of the three consultants and at least one advisor for each of the areas in which the university proposes to give graduate work. If doctoral work is involved in an area, both advisors shall visit. At each university the consultants will meet with the various appropriate officers (deans, librarians, etc.) and with the chairman of each department involved in the assessment. They will also meet with staff and students of at least some of the areas concerned. An advisor will spend most of his time with the staff and students of his area of expertise, but will also meet with the chairman and with senior officers if there are particular matters concerning his area on which he needs information from such sources.

D4. Apart from the initial meeting with the Discipline Group, the consultants may arrange other meetings with the Discipline Group, as they feel necessary or at the request of the Discipline Group, in either case after consulting ACAP.

D5. The consultants and advisors shall prepare reports as described in sections E and F.

E - Area Reports

E1. For each university, there shall be prepared an Area Report for each area in which that university offers or proposes to offer graduate work. These reports will be drafted by the two advisors in the area, even if only one visited, and are to be finalized in consultation with the consultants who visited the university.

E2. Each Area Report will deal with one university only and will cover the following:

(a) Fields - for each field, discuss faculty numbers, student numbers, courses given, course enrolments, quantity and quality of research output, number of master's and PhD degrees awarded, suitability of doctoral thesis topics, quality of doctoral theses

(b) Can the current staff deal with the number of students projected for five years? If not, what additions seem necessary? (Undergraduate load will need to be considered.)

(c) The location of the undergraduate training of the students

(d) Comment on the adequacy of research and study space (office space) for staff and students. Comment on other physical facilities, including computer adequacy and computer availability to the graduate student

(e) Discuss library resources on the basis of report supplied

(f) Examine and comment on admission standards and, if possible, on the academic quality of the graduate student body

(g) For doctoral programmes for each field indicate the quality of education offered the student, using the following categories:

(i) outstanding (e.g. comparable with the best in the world)

(ii) excellent (e.g. in the top four or five in Canada)

(iii) competent to good (e.g. there would be little hesitation in advising a good student to enter the programme)

(iv) questionable (e.g. either the quality is inadequate or further study is required to establish its adequacy)

The judgements should be justified by a discussion and should refer to the current state, but if any change (in either direction) can be confidently foreseen it should be reported.

E2. (h) List the fields of the area in which doctoral theses should at present be supervised with explanatory comment if desired (this is particularly important for programmes with fields in categories (iii) and (iv) but is requested for all programmes).

E3. Each Area Report shall be submitted to

(i) the university concerned

(ii) the consultants

(iii) ACAP.

Area Reports are NOT to be published or further distributed except that, if COU feels that an Area Report is relevant to the final COU discussion of the ACAP report, the Area Report will be made available to COU, but not for publication.

E4. All Area Reports will be distributed simultaneously.

E5. Each university will be invited to comment as it sees fit on each of its Area Reports. The university comments will be submitted to ACAP and transmitted by ACAP to the consultants and advisors. The university comments will NOT be published or further distributed, except to COU on its request as with Area Reports.

F - Consultants' Report

F1. After the deadline for receipt of comments on Area Reports from the universities, the consultants shall draft a single Consultants' Report. It will be based on the material described in D2, the Area Reports, the comments thereon and of course their university visits. It is important that the reasoning behind the recommendations in the Consultants' Report be apparent, and to this end they should include information from the Area Reports in any manner which seems to them to be appropriate for their own report which will be a public document. They may also obtain assistance from their advisors on general considerations concerning the development of the four areas in the province or more widely.

F2. In their report, the consultants shall:

(a) Give a general discussion of the current state of graduate training in mathematical sciences in Ontario including at least the following topics:

general level of quality

suitability of graduate programmes as preparation for subsequent employment

any significant gaps in coverage of fields

any overemphasis on some field(s)

summary of material in items E2(a) (d) and (e) of Area Reports

adequacy of research funding for support of graduate programmes

relationship to related disciplines.

(b) Discuss changes in field emphasis or in content of applicability of mathematical graduate training which should be expected and/or encouraged in the next decade.

(c) Discuss society's needs for holders of graduate degrees on a five to ten year basis and in this connection comment on the planned enrolments submitted by the universities. Discuss the likely number of well qualified applicants for admission, allowing for changing patterns of immigration, and compare with the universities' enrolment projections. (It is recognized that the consultants are not primarily experts on manpower projections and, while the above discussion is an essential part of the planning assessment, corrective recommendations will be made by COU only if there is a gross mismatch between the universities' enrolment projections on the one hand and the anticipated total of well qualified students or a reliable estimate of needs on the other.)

(d) Discuss the relationship between the size of programme (enrolment and field scope) and the quality of training it offers a student. Consider the role of postdoctoral fellows in this connection.

(e) Discuss any other general matters important for the development of graduate work in the mathematical sciences in Ontario.

(f) Make recommendations concerning the most significant points in the above discussions (or otherwise emphasize their importance).

(g) On the basis of detailed assessment, recommend the role to be played in the provincial pattern of graduate education in the mathematical sciences by every area proposed by a university. Some possible recommendations are: continuation in accordance with the official plan submitted by the university (C7 and C8), or a more restricted undertaking either in numbers of fields or students, or a larger or broader programme, or suspension of enrolment, or discontinuance of the programme, or continuation in some form if successful in an appraisal, or initiation of a new programme subject to appraisal, or joint programmes or cooperative ventures.

In all cases, it is important that the rationale for recommendations be clear and the consultants should give their judgement of the standard of each subfield by university in the same manner as described for Area Reports in item E2(g).

(h) Discuss the realistic possibilities for cooperative activity involving a mathematical sciences department and another department or institute, either mathematical or not, either in the same university or another. Make recommendations as seem appropriate for specific cases.

F3. The consultants shall submit a draft report to ACAP to permit ACAP to ensure that it meets the terms of reference listed in F2. The Consultants' Report will then be submitted to ACAP.

G - ACAP and COU Reports

G1. ACAP will then prepare a draft ACAP Report.

G2. ACAP shall send its draft Report with the Consultants' Report as an appendix to the universities and to the Discipline Group for comment on both these reports. At this stage, or during the preparation of the ACAP draft Report, there could be meetings between ACAP representatives and the Discipline Group and/or some universities, if any party requested such a meeting. There could also be referral of questions to the consultants by ACAP and any material provided by the consultants shall be published by ACAP if it has been used for its Report.

G3. The comments of the Discipline Group on the Consultants' Report will be published as will those of any university so requesting, but the comments on the ACAP draft Report will not be published.

G4. After receiving the comments, ACAP will prepare the final ACAP Report and submit it to COU with copies to OCGS, CDAS and the Discipline Group.

G5. COU will not take final action on the COU Report until it has allowed at least one month for the receipt of any written comment on the ACAP Report from universities, OCGS, CDAS or the Discipline Group. COU will decide what comments it will publish. As a minimum, COU will publish the COU Report and the ACAP Report including the Consultants' Report and those comments on the Consultants' Report that are to be published.

Appendix I

Mathematical Sciences Discipline Group

1. Establishment of Group

   a. On November 15, 1974, OCGS authorized the establishment of a Mathematical Sciences Discipline Group with the following membership: two from each university intending to carry on graduate work, and containing at least three persons working in each of the four areas: pure mathematics, applied mathematics, statistics, computing. If the persons nominated by the universities should not include three from each area, ACAP is to coopt additional professors to make up the necessary number. When there are matters for which it is desirable to have input from every university concerned with one of the four areas, the Discipline Group will be expected to establish ad hoc subcommittees.

   b. Changes of a university's representative are to be notified by the executive head.

   c. The Group shall select its own chairman.

2. Meetings

   a. The Discipline Group may meet at the call of its chairman or in accord with its own arrangements.

   b. The Discipline Group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. COU has instructed ACAP to conduct a planning assessment in the Mathematical Sciences and the Discipline Group will assist and advise ACAP and generally facilitate the assessment.

b. In the future, the Group is to keep under review the plans for graduate work in the Mathematical Sciences in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis. For this purpose ACAP will assist the group in obtaining information and data, as mutually agreed.

c. The Group may make recommendations to ACAP in connection with graduate work in the Mathematical Sciences when it considers it appropriate.

APPENDIX E

DISCIPLINE GROUP MEMBERSHIP

DISCIPLINE GROUP MEMBERSHIP

Brock	J. P. Mayberry (observer)
Carleton	D. A. Dawson
	J. D. Dixon
Guelph	C. K. Capstick, until September, 1976
	R. E. George
	T. D. Newton, until September, 1976
	R. G. Buschman
Lakehead	G. K. Fleming, until November, 1975
	C. F. Kent
	J. H. M. Whitfield
McMaster	K. A. Redish, until October, 1975
	M. A. Preston
	*C. R. Riehm
Ottawa	L. G. Birta
	R. Vaillancourt, until September, 1976
	W. D. Burgess
Queen's	J. Coleman
	D. A. Jardine
Toronto	*G. F. D. Duff, until May, 1975
	S. Smith
	T. E. Hull, until May, 1975
	P. Hume
Trent	J. W. Jury (observer)
Waterloo	J. D. Lawson
	D. A. Sprott, until July, 1975
	J. G. Kalbfleisch
Western Ontario	J. H. Blackwell, until September, 1976
	S. C. R. Dennis
	D. Borwein
Windsor	P. N. Kaloni
	F. W. Lemire
York	G. E. Denzel
	A. P. Trojan, until November, 1975
	H. K. Botta

*Chairman

APPENDIX F

ROLES OF ACAP AND OF DISCIPLINE GROUPS

Ontario Council on Graduate Studies

By-Law No. 3

A By-Law to establish a Committee on the Academic Planning of Graduate Studies.

1. The Ontario Council on Graduate Studies, recognizing the importance of providing for the continued and orderly development of graduate studies in the Ontario universities, establishes a Standing Committee to be known as the Advisory Committee on Academic Planning (abbreviation - ACAP).

Interpretation

2. In this By-Law,
   (a) "Committee" without further specification, means the Advisory Committee on Academic Planning;
   (b) "Council" or OCGS means the Ontario Council on Graduate Studies;
   (c) "Committee of Presidents" or CPUO means the Committee of Presidents of Universities of Ontario;
   (d) "university" means a provincially assisted university in Ontario;
   (e) "discipline" means any branch or combination of branches of learning so designated;
   (f) "discipline group" means a body designated as such by the Committee of Presidents of Universities of Ontario, and normally consisting, for any one discipline, of one representative from each of the interested universities;
   (g) "planning assessment" means a formal review of current and projected graduate programmes within a discipline or a group of disciplines;
   (h) "programme" signifies all aspects of a particular graduate undertaking;
   (i) "rationalization" means the arranging of graduate programmes in order to avoid undesirable duplication, eliminate waste, and enhance and sustain quality.

Membership

3. (a) The Committee shall consist of at least seven members of the professoriate in Ontario universities, some of whom shall be members of the Council.

   (b) The members of the Committee shall serve for such periods of time as the Council may determine, and they shall be selected in such manner as may provide for reasonable balance both of academic disciplines and of universities.

   (c) The members of the Committee shall be appointed as individuals.

Chairman

4. The Chairman of the Committee shall be named by the Council, and he shall have one vote.

Quorum

5. A majority of all members of the Committee shall constitute a quorum.

Functions

6. The functions of the committee shall be

   (a) To advise OCGS on steps to be taken to implement effective provincial planning of graduate development;

   (b) To promote the rationalization of graduate studies within the universities, in cooperation with the discipline groups;

   (c) To recommend, through OCGS, to CPUO the carrying out of planning assessments of disciplines or groups of disciplines and to recommend suitable arrangements and procedures for each assessment;

   (d) To supervise the conduct of each planning assessment approved by CPUO;

   (e) To respond to requests by CPUO to have a discipline assessment conducted by proposing suitable arrangements;

   (f) to submit to CPUO the reports of the assessments together with any recommendations which the committee wishes to make. A copy of the report shall be sent to Council.

Jurisdiction

7. In order that the Committee may discharge the functions described in Section 6 above, it shall be authorized

   (a) to request a university to provide such information pertaining to graduate studies as may enable the Committee to discharge its functions;

   (b) to request a discipline group to provide such information as may enable the Committee to discharge its functions;

   (c) to receive reports from the universities and from the discipline groups, and to comment and communicate with the universities and the discipline groups concerning such reports;

   (d) to convene a meeting of any discipline group for the purpose of discussing the development to date, and proposals for the future development of graduate studies in the discipline concerned;

   (e) to send one or more representatives to a meeting of a discipline group at the invitation of the discipline group;

   (f) to make such suggestions to a discipline group as may be deemed appropriate to the functions of the Committee;

   (g) to supervise the conduct of planning assessments, and to report thereon to the Committee of Presidents of Universities of Ontario;

   (h) generally to report and to make recommendations to the Council;

   (i) to seek and receive advice from appropriate experts;

   (j) to employ consultants in connection with planning assessments.

Procedures

8. The procedure to be followed by the Committee shall be as approved by the Committee of Presidents of the University of Ontario.

9. The Committee's function is solely advisory.

Effective Date

10. This By-Law shall take effect January, 1971.

F-4

ACAP DISCIPLINE GROUPS AND THEIR ROLES

1. Establishment of a Group

a. When it is considered desirable to activate planning of graduate work in some discipline(s) or interdisciplinary area, COU, on the advice of OCGS, will authorize the establishment of an ACAP discipline group, if it was not already approved and included in the May, 1968 list. If it is already authorized, ACAP may decide to set it up as described in paragraph b.

b. The Executive Vice-Chairman of ACAP will then invite the executive head of each university (including Waterloo Lutheran University) either to nominate a member of the discipline group or to indicate that his university has no plans for graduate study in this discipline in the next five years or so. If a university can state no plans for future graduate work in the subject, but feels that a watching brief is desirable, it may appoint an observer to the group.

c. Changes of a university's representative are to be notified by the executive head.

d. The group shall select its own chairman.

2. Meetings

a. A discipline group may meet at the call of its chairman or in accord with its own arrangements.

b. A discipline group may be called to meet by the Executive Vice-Chairman acting for ACAP.

3. Responsibilities

a. The group is to keep under review the plans for graduate work in its discipline in Ontario, including new developments and trends in the discipline, and to make reports to ACAP on a regular basis.

b. The group may make recommendations to ACAP in connection with graduate work in its discipline when it considers it appropriate.

c. ACAP will assist the group in obtaining information and data, as mutually agreed.

d. When COU has instructed ACAP to conduct a planning assessment, the discipline group will assist and advise ACAP in determining procedures and terms of reference, will report as requested and will generally facilitate the assessment.

Approved by OCGS March 22, 1973
and by COU April 6, 1973.

APPENDIX G

CURRICULA VITARUM OF THE CONSULTANTS

Consultants G1 - G3
Advisors G4 - G11

GARRETT BIRKHOFF

Born Princeton, New Jersey, January 10, 1911

A.B. Harvard, 1932
Honorary doctorates from:
Universidad Nacional de Mexico (1951)
University of Lille (1959)
Case Institute of Technology (1964)

Harvard University, Instructor, 1936-38
Assistant Professor, 1938-41
Associate Professor, 1941-47
Professor, 1947-
Putnam Professor of Pure and Applied Mathematics, 1969-
Consultant for various industrial and governmental laboratories

Guggenheim Fellow, 1948
Member, National Academy of Science
Member, American Academy of Arts and Sciences, Vice-President, 1966-67
Member, Association of Computing Machinery
Member, Mathematical Association of America, Vice-President, 1979-71
Member, American Mathematical Society, Vice-President, 1958-59
Fellow, American Nuclear Society
Member, American Philosophical Society
Member, Society of Industrial and Applied Mathematics, President, 1967-68
Member, Mexican Mathematical Society

Fluid mechanics; numerical analysis; reactor theory; modern algebra

Address: Department of Mathematics
Harvard University
1 Oxford Street
Cambridge, Massachusetts
02138

DAVID R. COX

Born Birmingham, England, July 15, 1924

B.A.	Cambridge, 1944
M. A.	Cambridge, 1950
Ph.D.	Leeds, 1949

Royal Aircraft Establishment, Junior Scientific Officer, 1944-46
Wool Industries Research Association, Scientific Officer, 1946-50
Statistical Laboratory, Cambridge, Assistant Lecturer, 1950-55
University of North Carolina, Visiting Professor, 1955-56
University of London, Birkbeck College, Reader, 1956-61
Professor, 1961-66
Bell Telephone Laboratories, Technical Staff, 1965
University of London, Imperial College of Science and Technology
Professor of Statistics, 1966-
Head of Department of Mathematics, 1970-74

Editor, Biometrika, 1966-
Fellow, Royal Society
Foreign Honorary Member, American Academy of Arts and Sciences
Guy Medals in Silver and Gold, Royal Statistical Society

Statistical methods; statistical theory; applied probability theory; operational research.

Address: Department of Mathematics
Imperial College of Science and Technology
180 Queens Gate
London, England
SW7 2HH

ALLAN H. MORRISH

Born Winnipeg, Manitoba, April 18, 1921

B.Sc.	Manitoba, 1943
M.A.	Toronto, 1946
Ph.D.	Chicago, 1949

University of British Columbia, Lecturer, 1949-50
Research Associate, 1951-52
University of Minnesota, Department of Electrical Engineering
Research Associate, 1953-55
Associate Professor, 1955-59
Professor, 1959-64
University of Manitoba, Department of Physics
Professor, 1964-
Head, 1966-

NRC Postdoctorate Fellowship, Bristol University, 1950-51
Guggenheim Fellow, Oxford University, 1957-58
Fellow, Institute of Physics
Fellow, American Physical Society
Fellow, Royal Society of Canada
Associate Editor, Canadian Journal of Physics, 1968-73
Member, NRC Physics Grant Selection Committee, 1969-71
Member, DRB Advisory Committee on Physics Research, 1967-73
President, Canadian Association of Physicists, 1974-75
Convenor, Physics Subject Division, Royal Society of Canada, 1972-73
President, University of Manitoba Chapter, the Society of the Sigma Xi, 1968-69

Cosmic rays; solid state physics; magnetism

Address: Department of Physics
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

DAVID R. BRILLINGER

Born Toronto, Ontario, October 27, 1937

B.A.	Toronto, 1959
M.A.	Princeton, 1960
Ph.D.	Princeton, 1961

Bell Telephone Laboratories, Member of Technical Staff, 1962-64
Princeton University, Lecturer, 1962-64
London School of Economics, Lecturer, 1964-66
Reader, 1966-69
University of California, Berkeley, Professor of Statistics, 1969-

Fellow, Institute of Mathematical Statistics
Fellow, American Statistical Association
Member, International Statistical Institute
Council Member, Institute of Mathematical Statistics, 1974-77
Council Member, Bernoulli Society for Mathematical Statistics and Probability, 1975-79
Associate Editor, the Annals of Statistics
Associate Editor, the Annals of Probability
Editorial Board, Journal of Multivariate Analysis
Miller Research Professor, 1973-74
Guggenheim Fellow, 1975-76

Applied probability; applications of statistics; random processes; statistical computing

Address: Department of Statistics
University of California
Berkeley, California
94720

JOHN E. HOPCROFT

Born Seattle, Washington, October 10, 1939

B.S.	Seattle, 1961
M.S.	Stanford, 1962
Ph.D.	Stanford, 1964

Princeton University, Assistant Professor, 1964-67
Cornell University, Associate Professor, 1967-72
Professor, 1972-

Member, National Science Foundation Advisory Panel for Computer Science, 1971-74
Editor, Managing Editor, SIAM Journal on Computing, 1972-74, 1974-

Finite automata; computer organization; programming languages

Address: Department of Computer Science
Cornell University
Ithaca, New York
14853

JAMES M. KENNEDY

Born Ottawa, Ontario, April 25, 1928

B.A.	Toronto, 1949
M.A.	Toronto, 1950
Ph.D.	Princeton, 1953

Atomic Energy of Canada Limited, Assistant Research Officer, 1952
Associate Research Officer, 1955
Director of Computing Services, 1956
Senior Research Officer, 1959
Principal Research Officer, 1964
University of British Columbia, Director of the Computing Centre, 1966-
Professor of Computer Science, 1968-
Acting Head, Department of Computer Science, 1968-69 and 1973-74

President, Canadian Information Processing Society 1971-72
Member, Canadian Information Processing Society
Member, Canadian Mathematical Congress
Member, Canadian Association of Physicists
Member, NRC Associate Committee on Computers, 1963-71
Associate Editor, INFOR, 1974-

Computer applications; mathematical software; operating systems

Address: Department of Computer Science
University of British Columbia
Vancouver, British Columbia

WILLIAM H. KRUSKAL

Born New York City, New York, October 10, 1919

S.B.	Harvard, 1940
M.S.	Harvard, 1941
Ph.D.	Columbia, 1955

Kruskal and Kruskal, Inc., Vice-President, 1946-48
Columbia University, Lecturer, 1949-50
University of Chicago, Instructor, 1950-51
Assistant Professor, 1951-57
Associate Professor, 1957-62
Professor, 1962-
Chairman, 1966-73
Dean, Division of Social Sciences, 1974-
Ernest DeWitt Burton Distinguished Service Professor, Department of Statistics and the College, 1973-

Fellow, Institute of Mathematical Statistics
Fellow, American Association for the Advancement of Science
Fellow, American Statistical Association
Fellow, American Academy of Arts and Sciences
Editor, Annals of Mathematical Statistics, 1958-61
President, Institute of Mathematical Statistics
Vice-President, American Statistical Association, 1972-74
Member, President's Commission on Federal Statistics, 1970-71
Chairman, Committee on National Statistics, 1971-

Linear hypothesis theory; nonparametric analysis; statistics and public policy

Address: Department of Statistics
University of Chicago
Chicago, Illinois
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WILHELMUS A. J. LUXEMBURG

Born Delft, The Netherlands, April 11, 1929

M.A. Leiden, 1953
Ph.D. Delft, 1955

Queen's University, Canadian National Research Fellow, 1955-56
University of Toronto, Assistant Professor, 1956-58
California Institute of Technology, Assistant Professor, 1958-60
Associate Professor, 1960-62
Professor, 1962-
Executive Officer for Mathematics, 1970-

Corresponding Member, Royal Academy of Sciences of Amsterdam, 1974-
Editor, North-Holland Mathematical Library Series

Functional analysis; spaces of measurable functions; integration theory; approximation theory; lattice theory; nonstandard analysis

Address: 817 South El Molino Avenue
Pasadena, California
91106

NATHAN S. MENDELSOHN

Born Brooklyn, New York, April 14, 1917

B.A.	Toronto, 1939
M.A.	Toronto, 1940
Ph.D.	Toronto, 1942

University of Toronto, Teaching Fellow, 1939-42
Queen's University, Lecturer, 1945-46
University of Manitoba, Assistant Professor
Associate Professor
Professor

Research Scientist, National Research Council
Research Scientist, Defence Research Board of Canada
Research Scientist, Inspection Board of the United Kingdom and Canada
Member, National Research Council, Propellants Sub-Committee of the Committee on Explosives
Fellow, Royal Society of Canada
President, Canadian Mathematical Congress, 1969-71
Member, National Research Council, Scholarship Selection Committee, 1969-71
Canadian delegate to the International Mathematical Union, Stockholm 1962, Moscow 1966, Nice 1970

Algebra; geometry; combinatorics

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